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SOIL-ASPHALT STABILIZATION WITH A LIME ADDITIVE

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR

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BY

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ABSTRACT

In recent years soil stabilization has begun to play an important part in highway construction on this continent. One of the older and more widely used methods of stabilization involved the addition of small amounts of an asphaltic material to the soil. To this date there have been about 6,700 miles of road constructed in the United States using a soil-asphalt stabilized base course. The majority of the work done in the field of soil-asphalt stabilization in Canada has been in the Province of Manitoba.

This investigation involved the stabilizing of a clean, poorly graded sand with an asphalt and a secondary additive of hydrated lime. The strengths of the specimens were measured by means of the Modified Hubbard-Field Stability test, the unconfined compression test, and the triaxial compression test. The strengths were measured after the specimens had been subjected to an air dry curing period, to freeze-thaw cycles, and to water immersion.

It was found that the addition of 3 per cent hydrated lime to the sand-asphalt mix increased the strength of the samples considerably. The addition of asphalt and hydrated lime decreased the angle of internal friction of the soil. A mix containing 4 to 5 per cent residual asphalt from an SS-1 emulsion and 3 per cent hydrated lime appeared to be satisfactory for use as a sand-asphalt base course material when covered with a suitable wearing surface.

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CHAPTER I

INTRODUCTION

During the past twenty or thirty years there has been a great increase in the importance of highways. Extensive developments in the motor vehicle industry have made possible the economical transportation of many commodities by means of motor trucks. The development of the motor vehicle and the increased highway construction programme have gone hand in hand. With this expanded highway construction programme, many agencies have been faced with a rapidly depleting supply of good quality aggregate with which to build the pavement structure necessary to carry the increasingly heavy volume of truck traffic. With this fact in mind, road builders have turned their attention to the use of local materials. Most of these local materials were of inferior quality and it was necessary to find some means by which the load bearing capacity of these soils could be increased so as to facilitate the use of the material in the highway pavement structure.

There are many areas on this continent where there is an abundance of sand; but where crushed coarse aggregate is scarce and costly. It was in areas such as these where attempts at using local materials with a stabilizing agent to improve the stability

of the soil were first made.

The use of a sand and asphalt mixture in road building has been known to highway engineers for many years. Sheet asphalt has been used for the past sixty or seventy years as a wearing surface over cement concrete or asphaltic concrete bases. (1)* In the design of sheet asphalt surfaces, the general procedure was to use a graded sand, mineral filler, and enough asphalt to substantially fill the voids after compaction. Due to the high percentage of asphalt, it was necessary to use large quantities of stone dust filler and a low penetration grade of asphalt cement in order to secure stability against displacement under traffic. Frequently the grading of the sand was specified within very narrow limits, based on the belief that grading was a critical factor in stability.

Sheet asphalt wearing surfaces in general have a splendid record, but all specifications have required critical control of design, mixing, and placing operations. High temperatures during mixing and costly paving plants were always required for this type of operation with the result that the cost of sheet asphalt was generally quite high.

Since the one serious disadvantage found with the sheet asphalt mixes was the high cost of heating and mixing, it was nec-

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* The numbers in parenthesis refer to the references in the bibliography at the end of this report.

essary to use fluid binders and a cold mixing process in order to reduce the cost of stabilizing native sands with asphalt. Fluidity of the binder was obtained by the use of volatile solvents in the cutback asphalts and tars, and by the use of water and an emulsifying agent in the asphaltic emulsions.

Not all sands were suitable for sand-asphalt stabilization. The gradation and the particle shape of the sand on some projects were such that, when combined with the asphaltic material, the mixture still had a very low stability. It soon became apparent that the stability of the sand or sand-admixture blend before treatment with asphalt was an important factor in obtaining successful results. Thus it was necessary to investigate each project to determine the feasibility of using the sand-asphalt mix.

During the past twenty years there have been many miles of road constructed using a sand-asphalt or soil-asphalt base course. In the United States there are presently about 2,000 miles of primary highway constructed using an asphalt stabilized base course material and slightly in excess of 4,700 miles of secondary road constructed with the same stabilized base material. (2) The Province of Manitoba has constructed approximately 65 miles of road using a sand-asphalt base material since 1950. Preliminary investigation of other proposed projects indicated that the strength of the mixed material was too low to be satisfactory for a sand-asphalt mix and as a result

these projects were abandoned in favor of a conventional gravel base course.

Purpose of this Investigation:

It was the purpose of this investigation, first of all, to review some of the more pertinent literature dealing with soil-asphalt stabilization. This review of literature is summarized in Chapter II.

The second section of this report deals with the construction of sand-asphalt stabilization projects in the Province of Manitoba. Particular attention is given to construction procedures, construction costs, and the present condition of the roadway. This material is presented in Chapter III.

In the final section, a laboratory testing programme was undertaken to try and stabilize a clean, poorly graded sand with an asphaltic material and a secondary additive. The asphaltic materials used were a 150-200 penetration grade of asphalt cement and a slow setting type, SS-1 emulsion. Hydrated lime was used as the secondary additive. The strength of the compacted samples was evaluated by means of the Modified Hubbard-Field Stability test, the unconfined compression test, and the triaxial compression test. The rate of water absorption, the expansion due to cycles of freezing and thawing, and the expansion due to water immersion were also

determined. Strength tests were performed on specimens subjected to air drying, water immersion, and cycles of freezing and thawing, in order to ascertain the effect of these various curing periods on the stability of the compacted specimens. In addition, a study of the effect of the molding water content of the sand-emulsion mix on the molded dry density and on the unconfined compressive strength of the specimens was included in the investigation. An outline of the testing programme is presented in Chapter IV. A presentation and discussion of the testing procedures comprises Chapter V, and a discussion of the test results is included in Chapter VI.

CHAPTER II

SOME ASPECTS OF SOIL-ASPHALT STABILIZATION

Over the past twenty or thirty years there has been considerable work done in the field of soil stabilization with asphalt. (3) Much of the early work in this field has been of a practical nature in that the results were applied directly to field construction. In the past few years there has been an increasing tendency to carry on investigations of a more scientific nature in order to attempt to solve some of the problems that have been encountered in this field.

Definition of Soil Stabilization:

Soil stabilization may be broadly defined as any regulated process that alters or controls the soil properties for the purpose of improving the capacity of the soil to perform an intended function. (4) Soil stabilization often involves the addition of a small amount of one or more materials to the natural soil. The stabilizing agents may be divided into three main groups. The first group involves the cementing agents. These materials are capable of reactions within themselves, or in the presence of water, whereby they produce strong inter-particle bonds between the soil grains and thus enable the stabilized soil mass to sustain high loads. The second group of stabilizers could be termed the soil modifiers or soil conditioners. These agents are generally surface active

materials that change the soil texture and soil structure and thus alter the properties of the soil mass. The third group of stabilizers is the waterproofing agents. Basically these agents tend to prevent water absorption by the soil mass and thus retard the loss of strength in the presence of water. In granular materials the waterproofing agents may also contribute to the cohesive strength of the soil.

Role of Asphalt in Stabilization:

The Committee on Soil-Bituminous Stabilization of the Highway Research Board in a recent questionnaire defined soil-asphalt stabilization as: "The treatment of naturally occurring non-plastic or plastic soil materials with liquid asphalts at ordinary temperatures which, after compaction, will provide waterproof base or subbase courses of adequate load bearing qualities. "(2) Some other authorities refer to the treatment of a non-plastic soil with asphalt as sand-asphalt stabilization, and the treatment of a plastic soil with asphalt as soil-asphalt stabilization. (3) In this report, soil-asphalt stabilization will be used to refer to the treatment of any soil with asphalt. Sand-asphalt stabilization is a particular kind of soil-asphalt stabilization dealing with the addition of asphalt to a non-plastic soil.

Asphalt has been used in soil stabilization largely because of its waterproofing characteristics. When the asphalt is mixed with

the soil, it forms a very thin waterproofing film around the individual soil grains or around groups of soil grains, thereby hindering the penetration of water into the stabilized soil mass. The role of the asphalt film in stabilizing the soil depends to some extent on the nature of the soil. In the case of the non-cohesive soils such as fine sands and silts, the asphalt film is used to waterproof the soil grains and to bind these grains together. With these non-cohesive soils the asphalt film increases the strength and load carrying capacity of the soil mass by acting as a binder as well as a waterproofing agent.

Most fine grained cohesive soils possess considerable strength when compacted and tested at the proper water content*. When asphalt is incorporated into these soils, the main purpose is to waterproof the soil and prevent the infiltration of water and the subsequent loss in strength. (5) The strength of the cohesive soils is due principally to the cohesive inter-particle bond. This bond is highly sensitive to the action of water. Thus the asphalt films must be distributed throughout the soil mass in order to protect this inter-particle bond and thus preserve the strength of the soil mass. (5)

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* Water content refers to the weight of water to the weight of soil dried to constant weight at 105 degrees Centigrade, expressed as a percentage.

Theories of Asphalt Stabilization:

Endersby has proposed two theories regarding soil-asphalt stabilization. (6) The "plug theory" regarding the action of asphalt in waterproofing the soil contends that the capillaries in the soil mass are simply plugged with bodies of asphalt, thus preventing the water from entering or leaving the mix. The "intimate mix theory" states that the individual particles of the soil are coated with a thin film of asphalt, thus preventing water from attacking the individual soil grains.

Both theories seem to hold true for certain soils. When dealing with asphalt stabilization of a fine grained cohesive soil, it is hardly possible that the individual particles can become coated with a thin film of asphalt since the surface area of the particles is so large. In this case the "plug theory" seems to be applicable. However, when dealing with a sandy material, it is quite conceivable that a thin film of asphalt could coat each individual particle. This idea is supported by the fact that the strength of the mixed material is usually greater than that of the natural sand. The strength of the compacted mix is greater because of the cohesive effect of the asphalt. This cohesive effect is dependent upon the thickness of the asphalt film and on the viscosity of the binder. The shearing resistance of a viscous film between two solid soil particles is

inversely proportional to the thickness of the film. Thus it is advantageous to have the film of asphalt as thin as possible in order to gain the maximum strength from the mix. It is also advantageous to use the hardest asphalt permissible in order to gain the highest strength. However, it must be kept in mind that mixes composed of hard asphalts are less flexible than those constructed with the softer asphalts. Also , thin films of asphalt are more susceptible to weathering than thick films.

Mixing Water Content:

It is practically impossible to mix cutback asphalts with dry soil since the asphalt will not coat the soil particles uniformly unless the mineral is very hot. The mixing is much easier when there is some water present in the soil. The film of water seems to lubricate the asphalt and facilitate the coating of the soil particles. There is a minimum water content at which good mixing is assured. Increases in the water content above this value give somewhat better distribution of the asphalt, but curing and compaction become difficult at these higher moisture contents. The amount of water needed for proper mixing varies with the soil type and the asphalt content. Benson and Becker found that mixing at the "fluff-point" gave satisfactory results. (7) The "fluff-point" is defined as the water content at which the soil becomes loose and "fluffy", with a

moist appearance. When this condition is passed the mix becomes cohesive and "muddy". The "fluff-point" exists over a range of moisture contents rather than at a single moisture content.

Effect of Mixer Type:

In connection with the laboratory testing of soil-asphalt mixtures it has been found that the type of mixer had a definite effect on the properties of the mix. (6)(7) In most cases the mixing time of two or three minutes seemed to be sufficient to produce a uniform mix. The results of investigations on this subject indicated that there was very little change in the properties of the mix with longer mixing periods. Much of the difference in the mix properties resulting from the different mixer types was probably due to differences in the dispersion of the asphalt throughout the soil.

Methods of Evaluating Mixtures:

There are numerous methods used to evaluate soil-asphalt mixtures. Probably the first two methods of determining the stability or strength of a soil-asphalt mix were the Modified Florida Bearing Value test and the Hubbard-Field Stability test.

Florida Bearing Value: Florida Bearing Value tests are used mainly for sand-emulsion mixes. With the Florida Bearing Value test on the untreated sand, a 600 gram sample of slightly dampened sand is compressed in a 3-inch by 3-inch cylindrical mold under a

1200 pound load. Testing of the sample is accomplished by gradually applying load to a one square inch surface. The unit load at a penetration of 0.1 inches is taken as the bearing value. From experience with sand-asphalt mixes it has been found that a sand having a Florida Bearing Value of 30 pounds per square inch or more was satisfactory for use in a sand-asphalt mix.

Testing of sand-asphalt mixes was done by means of the Modified Florida Bearing Value test. In this test the mixture is compacted in the 3-inch by 3-inch cylindrical mold and dried at 140 degrees Fahrenheit to a moisture content between 4 and 5 per cent, then tested while at that temperature and moisture. Loading is applied gradually to a one square inch surface and the load when radial cracks first appear or when the plunger has penetrated 0.25 inches is taken as the bearing value. A bearing value of 150 pounds per square inch at 140 degrees Fahrenheit is considered a safe minimum value. This test is actually a miniature California Bearing Ratio test in that a loaded area is forced into the compacted specimen confined by the steel mold.

Some users of the Modified Florida Bearing Value test advocate the use of the following formula to determine the amount of emulsified asphalt required in the sand-emulsion mix. (1)

$$P = 0.75(0.05A + 0.1B + 0.5C)$$

where:

A = per cent of sand retained on the No. 10 sieve*

B = per cent of sand passing the No. 10 sieve and retained on the No. 200 sieve.

C = percent of sand passing the No. 200 sieve as determined by a wet sieve analysis

P = per cent of emulsified asphalt required in the mix, based on the dry weight of sand.

Hubbard-Field Stability: The Hubbard-Field Stability test has found considerable use in the design of sand-asphalt mixes. There are many variations of the original method in use today. In the original method, 100 grams of mix is compacted in a 2-inch diameter mold under a static load of 9500 pounds. This static load is held on the sample for 5 minutes and then released. The sample is extruded from the mold and allowed to stand at room temperature before being placed in a water bath at 140 degrees Fahrenheit just prior to testing. In testing, the briquette is put in the testing mold and the load applied at the rate of strain of 0.1 inches per minute until failure. The load in pounds at failure is taken as the Hubbard-Field Stability. Strength as measured in the Hubbard-Field Stability test is actually some measure of a combination of internal friction

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* All Sieve sizes are United States Standard Sieve Series

and cohesion. (9) These two strength factors cannot be separated by an analysis of the test results. In this test, high stability values may result from using too little binder or a binder that is very hard. Such mixes may crack badly when in service.

Other Strength Tests: In recent years, use has been made of the Marshall Stability test, the unconfined compression test, and the triaxial compression test for the evaluation of the soil-asphalt mixtures.

Curing of Mixtures: As well as the numerous methods of determining the stability of soil-asphalt mixtures, there are also many methods of curing these mixtures. Specimens may be cured at air temperature or at various elevated temperatures prior to testing. Compacted samples may also be subjected to water immersion, to cycles of freezing and thawing, or to cycles of wetting and drying before testing in order to ascertain the effects of climatic conditions on the mixtures. The particular curing conditions used in any investigation of a construction project depend on the general conditions in the area of the project.

Types of Asphalt Used:

There are many types of asphaltic materials used in soil-asphalt stabilization. The particular grade used is dependent on the type of mixing operation, the type of soil, and on the climatic conditions in the area of the project.

Rapid and medium curing cutback asphalts can be used successfully with sandy soils in road mixing operations. The rapid curing asphalts seem to work best in clean, sandy soils. Soils containing some fine material are more easily stabilized with the medium curing type of cutback asphalt. Use of the medium curing asphalt gives more time for the dispersion of the asphalt throughout the soil before the fluidity of the binder decreases as a result of the loss of some volatile material.

Asphalt emulsions can also be used successfully in soil stabilization. (10)(11)(12)(13) The only grade of emulsion that is suited to mixing operations of any kind is the slow-setting or SS type. In general, emulsions are better suited to plant mixing operations than to road mixing operations. One distinct advantage of the emulsion is that it mixes very well with wet soils. These soils however must be aerated before proper compaction can be obtained. A soil-emulsion mix is much less affected by rain than is a soil-cutback asphalt mix in the uncompacted state.

Penetration grades of asphalt cement have been used successfully in the stabilization of clean sands. (23) Generally this material must be added to the sand by means of a travel plant similar to the P & H Single Pass Stabilizer. The slow curing varieties of cutback asphalts and the road tars have been used in many areas of the

United States to produce what are called "oiled-earth roads". Construction methods involving these asphalts are usually of the penetration type wherein the asphaltic material is applied to the entire width of the road and allowed to penetrate into the soil.

Csanyi has developed one of the latest methods of applying asphalt to the soil. (15(16) The process involves the use of foamed asphalt. In this process, asphalt cement and saturated steam are united in a nozzle and sprayed on the pulverized soil. Apparently the asphalt and steam follow the water phase in the soil system, thus affording an even distribution of the asphalt throughout the soil. The particular advantage of this method lies in the fact that little or no aeration of the mixed material is required before compaction can be started. This process also permits the use of a harder asphalt, thus increasing the stability of the compacted material somewhat. In the fall of 1961, the Province of Manitoba undertook an experimental project using foamed asphalt. The soil on this project was a typical A-7-5* Red River Valley gumbo. Due to poor weather conditions only a short section of the project was processed and as a result no information on this project is presently available.

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*Classification according to AASHO Designation M145-49

<u>Water Content for Mixing and Compaction:</u>

The effect of the water content at the time of mixing and compaction of the soil-asphalt mix on the various properties such as strength, water absorption, swelling, and air void content has been known for some time.

In 1958, Herrin presented a paper to the Highway Research Board dealing with some of the effects of the water phase in the soil-asphalt mix. (17) Batches of mix were made using water contents within the fluff-point range. In this series of tests the maximum water content used was 10 percent. It was found that the variations in the rates of evaporation of the water and volatiles from both the loose mixture and from the compacted mixture were similar. Evaporation of the volatile portion of the mix was quite rapid at first and then decreased with increasing time. Regardless of the amount of water used in the mixing or the amount of cutback used, the water evaporated out at a much faster rate than did the hydrocarbon volatiles of the cutback asphalt. The strength of the soil-asphalt mixtures was found to be inversely related to the amount of water and hydrocarbon volatiles present in the mixture. The strength of the compacted soil-asphalt specimens increased until the rate of evaporation of the volatile material from the uncompacted mix decreased to almost zero. After this point there

was very little change in strength with further drying. An increase in strength resulted from further evaporation of the volatile material from the compacted specimens. The dry density of the compacted soil-asphalt specimens tended to decrease as the water and hydrocarbon volatiles evaporated from the mixture and as a result the air void content increased as evaporation took place.

In 1960, Katti et al presented a paper to the Highway Research Board dealing further with the effect of the water phase of the soil-cutback asphalt mixture. (4) Medium curing cutback asphalts were used as the stabilizing agents in this study. The series of tests consisted of two parts. In the first part samples of cutback asphalt and soil were mixed at different water contents and molded immediately. In the second part samples of cutback asphalt and soil were mixed at one water content and dried back to various water contents before molding. The Iowa Bearing Value was used to determine the strength of the specimens. This test is similar to the Modified Florida Bearing Value test and the California Bearing Ratio test.

In this series of tests the degree of cutback asphalt dispersion in the soil mass was found to be a function of the amount of water present during mixing. In general, the higher the water content, the better was the dispersion of the asphalt. Compaction of the soil-cutback asphalt-water system immediately following

mixing produced a more stable specimen than a procedure in which a drying back period was included between mixing and compacting. Samples that were mixed at a high water content had the best dispersion of the asphaltic material through the soil mass, but such samples did not have the most desirable stability properties even when the mix was dried back from this high water content before compaction. The percentage of water required to produce maximum strength, maximum density, minimum total moisture absorption, and minimum expansion in the compacted specimens was different for each property mentioned. However, the range of water contents over which these minimum or maximum properties occurred was only several per cent. Thus it was possible to select what was called a compromise mixing water content (CMC) at which the variance of each of the properties from the optimum value was a minimum. It was found that this compromise mixing water content was very close to the water content at which maximum standard AASHO density in the soil-cutback asphalt-water system occurred. This value of compromise mixing water content depended upon the soil type, the type of asphalt, and the amount of asphalt used in the mix. This water content did not correspond to the lower fluff point water content.

It was also found that asphalt could be mixed with silty clay

materials if the amount of mixing water was such that the soil was close to its liquid limit. Mixing of such materials was nearly impossible when the soil was at its plastic limit. It was also found that there was an optimum duration of mixing of the soil-cutback asphalt-water systems for each type of mixing equipment.

Secondary Additives:

Quite recently investigators in the field of soil-asphalt stabilization have turned their attention to the use of certain other additives to be used in conjunction with the asphaltic material. The preliminary work that has been done in this field to date indicates that pronounced benefits can be derived from the conjunctive use of asphalt and certain secondary additives in the stabilization of fine grained soils. The use of an asphaltic material with certain cementitious additives such as phosphoric acid, hydrated lime, and normal portland cement appear to be most suitable for soil stabilization. (5)(18)(19)(20) Work has also been done with other secondary additives with trace amounts of certain chemicals in trying to stabilize fine grained soils.

The addition of phosphoric acid alone to the soil seems to increase the strength of the material considerably, but there is some loss of strength when the samples are subjected to water immersion or to cycles of freezing and thawing. The amount of

loss in strength is dependent upon the soil type.

Similar work undertaken with hydrated lime indicates that the lime alone does add considerable strength to the soil, but much of this strength is lost when the samples are subjected to cycles of freezing and thawing. (21)(22) Some investigations involving the use of hydrated lime in bituminous hot plant mixes seem to indicate that lime tends to decrease the water absorption and swelling of the compacted mix. (20)

Indications are that when asphalt is used in conjunction with such additives as phosphoric acid and hydrated lime, the asphaltic material waterproofs the soil mass and thus the soil retains the strength that has been imparted by the secondary additive. The systems containing asphalt and a cementitious additive respond to severe wetting and drying conditions more favorably than do similar soil mixtures with the secondary additive alone. (5) At compacting water contents around optimum these systems actually increase in strength when repeatedly wetted and dried, whereas the systems without asphalt tend to disintegrate.

It has also been found that asphalt tends to retard the additive-soil reactions. (5) The test results also indicate that soil-additive systems containing asphalt are less sensitive to variations in compaction water contents. Such moderating effects of the asphalt could be useful during construction operations.

CHAPTER III

CONSTRUCTION OF SAND-ASPHALT MIXES IN MANITOBA

There are numerous areas in the Province of Manitoba where the soil is predominantly sandy in nature. In some cases, with the absence of a readily available supply of good quality gravel, it has been found to be more economical to stabilize this native soil by some means and to use this stabilized soil as a base course material. This procedure was more economical than the importing of a gravel base course material from a considerable distance.

There is also another aspect to be considered regarding soil stabilization. When building a subgrade through a sandy area, considerable difficulty is often encountered in holding the material on the grade and in the prevention of ravelling under the effects of traffic. In cases like this it was necessary to look for some economical means of holding the sand in place. If the road carries a low volume of traffic and if there is a quantity of clay nearby, the sand grade may be capped with this clay and then traffic gravel placed on top of the capped grade. As long as the traffic volume is low, this type of construction will usually prove to be quite satisfactory. If there is a high volume of traffic on the road, then washboard and check holes are likely to develop.

Because of the two problems outlined, the Highways Branch of the Province of Manitoba became interested in sand stabilization. As a result of studies of various projects dealing with sand stabilization in the United States, it was decided to use asphalt as the stabilizing agent.

Project 1: Elm Creek to Rathwell:

The first sand-asphalt stabilization project was located on PTH No. 2 between Elm Creek and Rathwell, Approximately 50 miles south west of Winnipeg. (23) Early in the 1950 construction season contracts had been let for the construction of a new grade between Elm Creek and Rathwell. It appeared that grading operations would be completed by mid-season and as a result it was decided to commence the sand-asphalt stabilization project in the same construction season. Extremely wet weather during the summer held up the grading operations to such an extent that the grade was not quite completed by the end of the construction season. Nevertheless it was decided to go ahead with the stabilization operations as soon as enough grade had been completed.

Preliminary Investigation: The first step in the investigation of this project was to take samples of the soil from the top 8 or 10 inches of the grade and determine the grain size distribution of the material. Samples of a typical soil were then mixed with various amounts of asphaltic material. The asphaltic materials

used in this laboratory investigation were MC-3 and PMC cutback asphalts. The results of this investigation are shown in Table 1.

The total length of the section of highway involved in the test project was 23.5 miles. The soil in the area ranged from a very fine sand to a silty sand. These soils would fall into the A-4 or A-2-4 type according to the AASHO Soil Classification system. The soil was not well graded; having a high percentage of the material passing the No. 100 sieve and retained on the No. 200 sieve. The highway through this area had been maintained with a gravel surface for a number of years but had consistently given trouble because of the tendency for the development of washboard and chuck holes.

<u>Asphalts Used:</u> As this project was the first of its kind to be undertaken in Canada, the Department wished to determine the most satisfactory type of asphalt for local conditions of traffic and climate. With this idea in mind orders were placed for MC-3, MC-4, RC-3, SC-6, MIP, PMC, and Terolas asphalts. Terolas was an emulsified asphalt corresponding to the slow-setting mixing grades of emulsion manufactured today. The MIP and PMC were cutback asphalts designed for cold road mixing operations. Table II gives the various percentages and the various types of asphaltic materials that were used for the different sections of this test project.

TABLE I

PRELIMINARY INVESTIGATION

PTH No. 2 -- Elm Creek to Rathwell

Type of Asphalt	Per Cent Residual Asphalt	Laboratory Hubbard-Field Stability
MC-3	3.5	720
	4.0	930
	4.5	1060
	5.0	1180
	6.0	1200
	7.0	1260
PMC (Plant Mix Cold)	3.6	740
	4.2	970
	4.7	1120
	5.3	1220
	5.8	1220
	6.4	1250
	7.5	1270

TABLE II

ASPHALTS USED ON VARIOUS SECTIONS

PTH No. 2 -- Elm Creek to Rathwell

From Station	To Station	Type of Asphalt	Average Per Cent of Asphaltic Material Added
0+00	28+00	MC-3	6.0
28+00	56+00	RC-3	6.2
56+50	67+00	MC-4	7.1
67+00	86+00	PMC & MIP	7.0
86+00	116+00	PMC & MIP	6.3
116+00	134+00	MC-3	7.0
134+00	154+00	MC-3	6.4
154+00	160+00	MC-3	7.2
160+00	174+00	MC-3 & MC-4	6.4
174+00	183+00	MC-3 & MC-4	7.0
183+00	202+00	MC-3	6.9
202+00	213+00	MC-3	7.5
213+00	226+00	MC-3	6.4
226+00	242+00	MC-3	7.1
242+00	250+00	MC-3	6.9
250+00	267+00	MC-3 & MIP	7.9
267+00	280+00	MIP	7.3
280+00	290+00	Emulsion	7.5
290+00	311+00	Emulsion	7.1
311+00	315+00	Emulsion	7.7
315+00	316+00	Emulsion	8.5
316+00	325+50	MIP	7.1
325+50	327+00	MIP	8.4
327+00	583+75	MC-3	5.0
583+75	605+00	SC-6	4.7
605+00	1123+00	MC-3	5.0
1123+00	1242+79	Emulsion	5.4

Construction Procedures: The first step in construction was to blade and shape the roadway to the desired cross-section by means of motor patrols. This was essential since the P & H Single Pass Stabilizer* used for the mixing operations always cut to a uniform depth. Any variation between the original cross-section and the final cross-section would result in a variable depth of processed material rather than the uniform depth desired. Since the asphalt was added to the soil through the stabilizer at a constant rate, any variation in the quantity of material processed per foot of travel of the stabilizer would have resulted in a variable asphalt content.

After the grade had been shaped, the P & H Single Pass Stabilizer was used to pulverize the soil and add the asphaltic material. The stabilizer unit was equipped with three rotors, the first of which was a high speed cutting rotor that cut and pulverized the soil. The degree of cutting and pulverization depended upon the speed at which the unit was travelling. The second rotor or blending rotor turned in the opposite direction to the cutting rotor. Mixing was accomplished by means of a single pugmill equipped with wide faced paddles to provide a fast means of obtaining the maximum efficiency in mixing and assuring a thorough coating of the soil particles with asphalt. The back of the unit had an adjustable tail

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* Unit manufactured by the Harnischfeger Corporation, Milwaukee, Wisconsin

gate to strike off the mixed material to a uniform loose density. This was of importance when dealing with mixed materials that required no aeration.

The P & H Stabilizer used on this project was capable of processing an eight foot section of the roadway. The total width of grade stabilized was twenty-four feet; making three passes of the stabilizer necessary. The first pass was made on the centre-line of the grade, the second pass in the opposite direction along one side, and the third pass in the same direction as the first pass along the other side. Some authorities favored moving the stabilizer back after each pass and processing in a forward direction on all three passes, however no apparent difficulty was experienced with the method used.

The stabilizer was equipped with an adjustable valve and a meter to control the quantity of asphalt put through the machine. With the speed and cutting depth of the stabilizer and the dry density of the soil in the grade known, the quantity of soil processed per minute was determined. Using the desired percentage of asphalt, the quantity of asphalt per minute required to give this asphalt content was then calculated. The valve on the asphalt line was then adjusted until the desired number of metered gallons of asphalt per minute was obtained.

The operating speed used on the majority of this project was 25 feet per minute. This speed was reduced to 19 feet per minute on some sections where satisfactory pulverization of the soil could not be obtained at the higher speed. For every change in speed the valve on the asphalt line had to be adjusted accordingly. In order to simplify the field control, a chart showing the number of gallons of asphalt per square yard required for the various asphalt contents, cutting depths, and dry densities of the in-place material was drawn up. Another chart showing the number of metered gallons per minute required to give the various gallons per square yard for the different operating speeds was also used.

Construction operations were usually carried on over a section of approximately one-half mile in length. Aeration of the processed material was generally started as soon as mixing operations on the section were completed. Aeration was accomplished by means of two motor graders and two pulvi-mixers working in a train. The graders cut about a 2 inch depth of material with each pass and moved it into windrows. The pulvi-mixers followed along the windrow and were operated with open tail gates in order to increase the efficiency of aeration. This operation was continued until almost all the stabilized material was in the windrow. If further aeration was required, the graders then brought the material

to the other side of the road. This operation was completed in three passes, with the pulvi-mixers following the graders on each pass.

Aeration was continued until the total moisture and volatile content was below 6 per cent and the stability of the mixed material reached 1200 pounds as measured by the Modified Hubbard-Field Stability test. This maximum allowable moisture content of 6 per cent was set arbitrarily. It was found later that the maximum allowable moisture content for compaction varied somewhat with the soil type. When this condition was reached, laying out and compaction of the mix was commenced. Approximately two-thirds of the mixed material was spread over the entire width of the roadway for the first lift; leaving the remainder of the material in the windrow for the second lift.

Compaction of the first lift was accomplished with the use of sheepsfoot and rubber tire rollers. Only rubber tire rollers were used for the compaction of the second lift. A steel wheel roller was tried for the final lift but it resulted in a lamination at the surface which peeled off under traffic. Use of the steel wheel roller was discontinued and final compaction was done entirely by means of rubber tire rollers.

At the start of the project it was intended that mixing operations would not commence until the moisture content of the sand was below 5 per cent. Due to unfavorable weather conditions this limit was gradually raised to 15 per cent. No adverse effects were encountered from mixing at these higher water contents though satisfactory compaction could not be obtained until the total moisture and volatile content of the mixed material was reduced to between 2 and 6 per cent, depending on the nature of the soil. Laying of the mixed material was also controlled by running Modified Hubbard-Field Stability tests on samples of the material taken from the windrow. At first, compaction was not permitted until a stability of 1200 pounds was reached. This requirement was later relaxed to permit laying operations to be started when the Modified Hubbard-Field Stability of the mix reached 1000 pounds. As long as good drying weather prevailed it was felt that aeration was continuing while the test was being run and would also continue to some extent while the mixed material was being shaped and compacted.

The weather in the fall of 1950 was very poor and thus it was impossible to aerate the mixed material sufficiently in order to reduce the moisture content to a value which would permit compaction. As a result, in mid-November the entire area that had been treated up to that time was shaped, rolled lightly, given a temporary

fog coat of MC-0, and left for the winter. Traffic during the winter caused some ravelling but no serious distress developed.

Suitability of the Various Asphalts: Early in the following year aeration of the mixed material was resumed and the processing of the remainder of the material on the project was started. Most of the material that had been mixed in the fall of 1950 was reprocessed in the spring with about 2 per cent additional asphalt added. From the work that had been carried out in 1950 it was found that the MC-3 asphalt yielded the lowest cost per mile. As a result most of the work carried out in 1951 used the MC-3 asphalt, although some sections were constructed using SC-6 and emulsified asphalts.

The SC-6 proved to be very difficult to mix and lay, but gave good stabilities. This type of asphalt had an additional advantage in that no aeration was required. The only type of asphalt that was unsatisfactory was the RC-3. It was felt this was probably due to the very wet weather experienced during the construction operations. The Terolas emulsion was relatively easy to mix and lay, but more gallons per square yard of processed material were required and as a result the cost was higher. This asphalt had a tendency to gum the valves on the trucks and on the stabilizer. However it required no heating. Much of the trouble with this asphalt could have been prevented by cleaning the tanks and the lines of any previous asphalt before using the emulsion.

Void Content: The void content* of the sand-asphalt mixtures after compaction in the 2-inch diameter Modified Hubbard-Field mold was approximately 25 per cent. This was much higher than the void content encountered in either sheet asphalt or conventional asphaltic concrete mixes. This high void content was probably due in part to the poor gradation of the sand. Thus there was not feasible asphalt content where the voids in the aggregate would become completely filled with asphalt. The gradation of typical materials encountered on this project are shown in Table III.

Preliminary Investigation: Brokenhead River to Reynolds:

In view of the success of the test project, sand-asphalt stabilization was next considered for a section of the Trans-Canada Highway from the Brokenhead River to Reynolds. Sand from this area had roughly 75 per cent of the material passing the No. 40 sieve and retained on the No. 80 sieve. Samples of sand from the top of the grade were obtained. Typical samples were then mixed with various amounts of asphalt and Hubbard-Field briquettes made from the various mixes. The asphaltic materials used in this preliminary laboratory investigation were MC-3 cutback asphalt and emulsified asphalt. The Modified Hubbard-Field Stability values for the briquettes were determined and the results obtained are shown in

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* Void content refers to the ratio of the volume of voids in the compacted mix to the volume of the compacted mix, expressed as a percentage.

TABLE III

TYPICAL SIEVE ANALYSES OF SANDS

Elm Creek to Rathwell

Sieve Size	Per Cent Passing			
No. 10	100	100	100	100
No. 40	98	100	95	100
No. 80	96	97	72	98
No. 100	92	95	67	95
No. 200	23	31	10	30

Table IV. The strength of all briquettes fell far below the minimum value of 1200 pounds and as a result this project was abandoned in favor of a conventional crushed gravel base course and a hot plant mix bituminous surface.

Projects 2 & 3: Sidney to Camp Hughes:

In 1954 another section of the Trans-Canada Highway approximately 100 miles west of Winnipeg was investigated to determine the suitability of sand-asphalt stabilization. This area was commonly known as the Carberry sand hills. As in the previous investigations, an extensive survey of the material in the top 8 to 10 inches of the grade was made and the grain size distribution of the soil determined. Based on experience gained from the first project, the sand in some areas appeared to have a satisfactory gradation whereas other areas contained material with excessive percentages of particles passing the No. 200 sieve. The asphaltic material could not be successfully incorporated into the sandy loam soils that contained high percentages of the soil particles finer than the No. 200 sieve. The sandy loam was in an area that covered about 7 miles of the proposed project. This 7 mile section was between areas containing sands that could be stabilized. Since there were no known gravel deposits in the area that could be used for a gravel base course, it was decided to import suitable sands

TABLE IV

PRELIMINARY INVESTIGATION FOR STABILIZATION

Trans-Canada Highway - Brokenhead River to Reynolds

Type of Asphalt	Per Cent Residual Asphalt	Modified Hubbard-Field Stability
	3.0	250
	4.0	250
MC-3	5.0	220
	6.0	210
	7.0	165
	4.0	390
Emulsion	5.0	465
	6.0	645

into the areas in which the native soil could not be stabilized, and to proceed with the project.

Use of the SC-6 asphalt had not proven too satisfactory on the test project but it was found that a similar asphalt, 150-200 penetration asphalt cement, had been used successfully in Minnesota. The major difference between the Elm Creek to Rathwell project and the one in Minnesota was in the sand gradation. The material on the Minnesota project was a relatively clean, well graded sand, with less than 10 per cent of the particles finer than the No. 200 sieve. The test project in Manitoba had material containing about 25 per cent of the particles finer than the No. 200 sieve.

It was decided to try the asphalt cement on this project for two reasons. First of all there would be little aeration of the mixed material required since there were no volatiles in the asphalt cement. Secondly the harder asphalt would give a higher stability of the compacted mix. It was assumed that sands containg up to 10 per cent of the particles finer than the No. 200 sieve could be effectively stabilized with the asphalt cement. With this in mind, it was found that approximately one-third the mileage between Sidney and Camp Hughes could be treated with this type of asphalt. The remainder of the sand on this project was stabilized with MC-3 cutback asphalt. The P & H Single Pass Stabilizer was used for

the mixing operations. This project was broken down into two contracts and was completed in the construction seasons of 1956 and 1957. Typical sieve analyses of the material are shown in Table V.

The residual asphalt content of the mixed material on this project ranged from 5 to 6 per cent. Modified Hubbard-Field Stability tests were run on the mixed material from the windrow. Laying out and compaction of the mixed material was not permitted until the total moisture and volatile content was below 6 per cent. The Modified Hubbard-Field Stability of the mixed material had to be a minimum of 1000 pounds before compaction operations were permitted. Typical field test results are shown in Table VI. The densities were taken by means of a sand cone after compaction of the mixed material was completed.

The surface of the compacted material was given a temporary fog coat of MC-0 immediately after construction. The sand-asphalt base was then covered with 3 inches of hot plant mix bituminous surfacing material. This section of highway has given excellent service to this date.

TABLE V

TYPICAL SIEVE ANALYSES OF SANDS

Trans-Canada Highway -- Sidney to Camp Hughes

Sieve Size	Per Cent Passing					
No. 10	100	100	100	100	100	100
No. 40	99	97	97	88	58	100
No. 80	61	41	21	15	9	74
No. 100	43	24	11	9	6	41
No. 200	15	7	4	2	3	5

TABLE VI

TYPICAL DENSITIES AND STABILITIES

Trans-Canada Highway - Sidney to Camp Hughes

Type of Asphalt	Dry Density of Mix - (pcf)	Modified Hubbard-Field Stability - (pounds)
	104.1	1297
	104.3	1295
	103.2	1181
MC-3	105.6	1381
	106.1	1686
	107.5	1832
	98.1	1013
	116.8	1456
	110.9	1037
150-200 Penetration Asphalt Cement	117.2	1734
	116.1	1852
	111.5	1240
	104.7	1165
	116.7	1842
	115.0	1410

Project 4: Elm Creek to Carman:

In view of the success of the three completed sand-asphalt stabilization projects, a fourth such project was undertaken on PTH No. 13 between Elm Creek and Carman, approximately 45 miles south west of Winnipeg. This project was in the same general area as the test project constructed in 1950 and 1951. The data in Table VII indicates that the gradation of the sand on this project was similar to that of the material encountered on the test project.

This contract was divided into two parts, with MC-3 cutback asphalt being used for the first 4 miles and SS-1 emulsified asphalt used on the remaining 4 miles. The residual asphalt content was between 5 and 6 per cent throughout the entire project. The P & H Single Pass Stabilizer was used for the mixing operations.

The sand-asphalt stabilized base course was given a temporary fog coat of MC-0 immediately after compaction. The stabilized base was then given a seal coat. This section was given a second seal coat in 1961. Performance of the road to this date has been excellent.

Project 5: Gladstone to Arden Ridge:

The most recent sand-asphalt stabilization project undertaken was on PTH No. 4 between Gladstone and Arden Ridge, approximately 100 miles north west of Winnipeg. Typical gradations of

TABLE VII

TYPICAL SIEVE ANALYSES OF SANDS

PTH No. 13 --- Elm Creek to Carman

Sieve Size	Per Cent Passing			
No. 10	100	100	100	100
No. 40	98	99	100	99
No. 80	92	96	98	96
No. 100	88	94	95	92
No. 200	24	39	21	13

the sands encountered on this project are shown in Table VIII.

The contract for the construction of the grade through this area was awarded early in 1959. At the same time a separate contract for stabilizing the sand with asphalt was tendered. This stabilization contract required the contractor to commence mixing operations on each mile of highway as soon as grading operations were completed. The sand on this project was very finely graded. As soon as the top of the grade dried out the material became very loose and ravelled. It was felt that if the material in the grade was stabilized as soon after construction as possible, this would minimize the difficulties of motorists in driving through the construction area.

Stabilization operations were started in July of 1959 using the P & H Single Pass Stabilizer and MC-3 cutback asphalt. Due to very heavy precipitation in the area that year, only approximately 8 miles of the grade could be stabilized. The moisture and volatile content of the mixed material was so high that the majority of the mix could not be compacted properly. As winter approached the mixed material was leveled with a motor patrol and rolled lightly. The surface of the processed material ravelled in some locations but it was much superior to the untreated soil. The processed material was also effective in preventing further moisture from soaking into the top of the grade.

TABLE VIII

TYPICAL SIEVE ANALYSES OF SANDS

PTH No. 4 -- Gladstone to Arden Ridge

Sieve Size	Per Cent Passing					
No. 10	100	100	100	100	100	95
No. 40	100	99	97	91	95	75
No. 80	99	97	88	67	51	36
No. 100	98	96	77	53	35	26
No. 200	35	49	15	19	14	8

As soon as weather conditions in the following spring would permit, the processed material was aerated and compacted. There were only one or two very short sections that required about 2 per cent additional asphalt. No apparent adverse effects resulted from leaving the processed material in a loosely compacted state over the winter months. Stabilization operations were carried out on the remainder of the road in the spring of 1960 as well.

The asphaltic materials used on this project were MC-3 cutback asphalt, SS-1 emulsified asphalt, and a small amount of 150-200 penetration asphalt cement. This sand-asphalt base course was covered with 3 inches of hot plant mix bituminous surfacing material in the summer of 1960.

General Comments on Projects:

Since 1950 the Province of Manitoba has used a sand-asphalt base course on approximately 65 miles of highway. The P & H Single Pass Stabilizer was used for incorporating the asphalt into the soil on all projects. In general the stabilizer was operated at a speed of 25 feet per minute. All stabilization was done to a 6 inch depth of compacted material. In order to get the 6 inches of compacted soil it was found that the loose depth of mix as it was left behind the stabilizer had to be about 9 inches. The stabilizer could process between 7,000 and 10,000 square yards of material

per day. No definite time could be set for aeration and compaction since this depended upon the moisture content of the soil at the time of mixing, on the soil type, and on the general weather conditions.

Stabilization of the soil as soon as the grade was completed proved to be quite helpful in allowing the movement of traffic through the project. On all projects the treated material was given a light fog coat of MC-0 as soon as compaction was complete in order to prevent ravelling of the mix under traffic. No apparent detrimental results have been experienced from leaving the processed material in a loose state over the winter months. Some small areas required only about 2 per cent additional asphalt, but in general it was only necessary to aerate and compact the mix in the following spring. Asphaltic materials have been successfully incorporated into soils having moisture contents as high as 15 per cent with no apparent adverse effects. The only disadvantage found from mixing at these high moisture contents was the increased amount of aeration required before compaction could be attempted. It was found that the moisture content of the mixed material had to be between 2 and 6 per cent before proper compaction could be obtained. The allowable moisture content at which compaction could be accomplished depended on the type of soil.

Wearing Surfaces Used: The sand-asphalt base course on about half of the mileage was covered with 3 inches of hot plant mix bituminous surfacing material, with the wearing surface on the remainder of the 65 miles being a seal coat. On both projects where the wearing surface consisted of a seal coat, the surface has required one additional treatment since the time of construction. All roads constructed with the sand-asphalt base course have performed quite well. The test project on PTH No. 2 between Elm Creek and Rathwell is showing some signs of distress at present, but this could be corrected by placing a hot plant mix bituminous mat over the present sand-asphalt base and seal coat.

Cost of Stabilization: The cost of the various sand-asphalt stabilization projects is shown in Table X. The average cost of 6 inches of asphalt stabilized material was about $0.76 per square yard. Assuming a compacted dry density of conventional gravel base course of 135 pounds per cubic foot, one square yard of this material, 6 inches deep, would require about 610 pounds of aggregate. For the sand-asphalt base course and the gravel base course to have equal costs, the price of the conventional gravel base course would have to be in the neighbourhood of $2.50 per ton. It is quite likely that the cost of gravel base course on these stabilization projects would have been at least $2.50 per ton since there were very limited gravel deposits available.

TABLE IX

SAND-ASPHALT PROJECTS IN MANITOBA

Project Number	PTH	Location	Mileage	Year Constructed
1	2	Elm Creek - Rathwell	23.5	1950-1951
2	1	Camp Hughes - Carberry	12.4	1956-1957
3	1	Sidney - Carberry	8.2	1957
4	13	Elm Creek - Carman	8.0	1958
5	4	Gladstone - Arden Ridge	12.6	1959-1960

TABLE X

STABILIZATION COSTS AND TRAFFIC VOLUMES

Project Number	Stabilization Width - (ft)	Cost Per Sq. Yard	Cost Per Mile	Current ADT
1	24	$0.74	$10,440.00	800
2	46	0.78	21,400.00	2000
3	46	0.83	22,500.00	2250
4	24	0.73	10,350.00	500
5	44	0.73	17,000.00	1200

Deflection Studies: The results of the Benkleman beam deflection tests taken on the sand-asphalt stabilization projects are shown in Table XI. These deflections are fairly uniform throughout the seasons and the average deflection is quite low when compared to conventional surfacing projects. It should be mentioned however that the subgrade on these stabilization projects was fairly well drained. The material in the subgrade was far from being saturated and as a result there was very little damage to these sections of highway due to frost action.

In general very favorable results have been experienced with all sand-asphalt base course projects constructed in Manitoba. The construction cost of the sand-asphalt base course has compared favorably with that of conventional gravel base course. No major maintenance has been required on any of the stabilized sections. In addition there was a further advantage in that the asphalt stabilized base course provided an additional waterproof layer in the pavement structure.

TABLE XI

BENKLEMAN BEAM DEFLECTIONS ON SAND-ASPHALT PROJECTS

Project Number	Control Section	Average Deflections -- 1960						
		April	May	June	July	Aug.	Sept.	Oct.
1	3003030	34	44	46	24	25	--	46
2 & 3	5001030	22	39	39	40	32	28	--
4	3013012	34	30	33	31	27	--	23
5	5004040	--	--	--	--	--	25	--

Project Number	Control Section	Average Deflections -- 1961						
		April	May	June	July	Aug.	Sept.	Oct.
1	3003030	38	46	40	35	34	--	32
2 & 3	5001030	32	34	35	--	--	--	24
4	3013012	26	24	24	27	--	--	30
5	5004040	27	28	24	--	--	--	19

Note: All deflections are in units of 0.001 inches. Deflections were taken in accordance with the procedure set out by the Canadian Good Roads Association.

CHAPTER IV

THE TESTING PROGRAMME

It has been found in Manitoba that certain sands could not be effectively stabilized with an asphaltic material. These sands were generally poorly graded, and contained little or no material passing the No. 200 sieve. Such a sand was selected for the following testing programme and attempts were made to stabilize this soil by the use of 150-200 penetration asphalt cement and SS-1 emulsified asphalt, with hydrated lime used as a secondary additive. The effect of the water content at the time of compaction on the strength and dry density of the sand-emulsion mix was also included as a part of this investigation.

Materials:

Soil: The soil used was a very clean sand from a section of PTH No. 52 near the town of Marchand, located approximately 40 miles south east of Winnipeg. The gradation of the sand is shown in Table XII. Approximately 98 per cent of the particles passed the No. 40 sieve, with 3 per cent passing the No. 200 sieve. The uniformity coefficient, C_u, of the material was 2.05 indicating a fairly uniformly graded material. A standard AASHO compaction test indicated the maximum dry density of the soil was 103 pounds

TABLE XII

SOIL PROPERTIES

AASHO Classification	A-3
Standard AASHO dry density	103.0 pcf
Optimum moisture content (Std. AASHO)	14.0 per cent
Specific gravity	2.63
Angle of internal friction	31 degrees
Uniformity coefficient (C_u)	2.05

Grain Size Distribution

Sieve Size	Per Cent Passing
No. 10	100
No. 40	98
No. 80	68
No. 100	34
No. 200	3.0

per cubic foot at an optimum moisture content of 14.0 per cent. According to the AASHO Soil Classification system this sand would be classed as an A-3 material. Using the Unified Soil Classification system this material would be of the SP type. A drained triaxial compression test on the natural sand showed an angle of internal friction of 31 degrees and a unit cohesion of 1.5 pounds per square inch. This unit cohesion is probably due to an error inherent in the apparatus.

Asphaltic Materials: The 150-200 penetration grade of asphalt cement used in this investigation was the same grade as used by the Province of Manitoba in the construction of hot plant mix bituminous surfacing material. An analysis of the asphalt cement is shown in Table XIII. The asphaltic emulsion was the slow-setting, SS-1 grade as manufactured by T. J. Pounder and Company of Winnipeg. An analysis of this material as supplied by the manufacturer is shown in Table XIV.

Hydrated Lime: The hydrated lime was a "Hi-Calcium Lime" as supplied by the Winnipeg Supply & Fuel Co. The chemical analysis shown in Table XV was carried out by the Manitoba Highways Testing Laboratory and the gradation was obtained from the supplier. This hydrated lime was similar to that used by Watt. (22)

TABLE XIII

ANALYSIS OF 150-200 PENETRATION ASPHALT CEMENT

Flash Point (Cleveland Open Cup -- degrees F)	595
Penetration at 77 degrees F (100 grams, 5 seconds)	182
Ductility at 60 degrees F (5 cms. per minute)	100+
Loss on Heating (50 grams, 5 hours at 325 degrees F)	0.1
Penetration at 77 degrees F (100 grams, 5 seconds) after heating to 325 degrees F.	175
Per cent of original penetration	96
Solubility in CCl_4 (per cent)	99.9
Homogeneous, Free from Water and Sediment	OK

TABLE XIV

ANALYSIS OF SS-1 EMULSIFIED ASPHALT

Per cent residual asphalt	64.8 per cent
Saybolt Furol viscosity at 77 degrees F	45 seconds
Cement mixing test (No. 14 sieve)	0.8 per cent
Penetration of residue	160
Sedimentation in 5 days	3 per cent
pH	8.7
Sieve test (per cent retained on No. 20 sieve)	OK

TABLE XV

ANALYSIS OF HYDRATED LIME

Calcium Oxide (CaO)	70.9 per cent
Magnesium Oxide (MgO)	0.4 per cent
Loss in Ignition	25.6 per cent
Other Constituents	3.1 per cent

Gradation

Sieve Size	Per Cent Passing
No. 48	100.0
No. 65	99.4
No. 100	98.8

Scope of the Testing Programme:

Mixes were made up to contain 2, 3, 4, 5, and 6 per cent residual asphalt* using the SS-1 emulsified asphalt and the 150-200 penetration grade of asphalt cement. At each residual asphalt content further mixes were made to contain 1 and 3 per cent hydrated lime. All percentages referred to are on the basis of the dry weight of soil. The soil, asphalt, and secondary additive were mixed in a Hobart Kitchen mixer.

The unconfined compression test and the Modified Hubbard-Field Stability test were used to evaluate the strength of the compacted specimens. Nine unconfined compression samples and six Hubbard-Field samples were made from each batch of material The unconfined compression samples were subjected to air dry, freeze-thaw, and water immersion curing periods. The Hubbard-Field samples were tested after air drying and after water immersion. The rate of water absorption and the expansion of the unconfined compression samples were determined during the water immersion test. The amount of swelling and the amount of water absorption were measured for those unconfined compression samples that were subjected to the freeze-thaw cycles.

The effect of the molding water content on the density and the strength of the 2-inch by 5-inch statically compacted specimens

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* Residual asphalt content refers to the percentage of asphalt cement in the specimen, based on the dry weight of aggregate.

was determined for a mixture containing 5 per cent residual asphalt from the SS-1 emulsion and for a mixture containing 5 per cent residual asphalt from the SS-1 emulsion and 3 per cent hydrated lime. After air curing for a period of one to two weeks these specimens were immersed in water and the amount of water absorption measured. After the water immersion period the samples were tested in compression.

Triaxial compression tests were run on samples of mix containing 5 per cent residual asphalt from the SS-1 emulsion. Separate mixes were made up to contain no hydrated lime and to contain 3 per cent hydrated lime at the residual asphalt content of 5 per cent. Five samples were run at different confining pressures for each Mohr envelope and envelopes were determined at three different rates of strain.

The effect of hydrated lime and mineral filler on the mix properties were compared by molding 2-inch by 5-inch samples from mixes containing no secondary additive, mixes containing 3 per cent hydrated lime, and mixes containing 3 per cent mineral filler. All samples were air dried at room temperature for a period of two weeks and then immersed in water for 44 days. After this water immersion period the samples were surface dried with a paper towel and tested in unconfined compression.

CHAPTER V

TESTING PROCEDURES

Mixing of the Materials:

All materials were mixed in a Hobart Model A-200* kitchen mixer capable of being operated at three speeds. It was found that the sand had to contain some water before the SS-1 emulsion could be effectively incorporated. If the moisture content of the sand at the time of mixing was too low, the emulsion would break before coating the sand grains. After mixing several trial sand-emulsion samples at different moisture contents, it was found that a mixing water content of about 14 per cent was the lowest value that could be used in order to obtain a uniform mix. This minimum mixing water content seemed to vary slightly with the amount of emulsion added to a given weight of soil, but because this variation was so small, all samples containing no hydrated lime were mixed at a water content of 14 per cent. The addition of hydrated lime required the use of a higher mixing water content. It was found that if an additional amount of water equal to the weight of hydrated lime was added, the resultant mix was satisfactory.

All batches were composed of 5000 grams of dry soil. The required amount of mixing water was measured in a graduate and

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* Manufactured by the Hobart Manufacturing Company, Troy, Ohio

added to the soil. The soil and water were then mixed in the Hobart mixer and allowed to stand for a period of 5 minutes to allow the water to disperse throughout the soil. The required amount of SS-1 emulsion was then measured in a graduate and put into the mixer. Surplus emulsion was washed from the side of the graduate with about 10 cubic centimeters of water and put in the mixer. The mixer was then turned on at the slow speed for about 15 seconds and then put on the high speed for 1 minute. The mixer was then stopped and the sides of the mixing bowl scraped. This was followed by another 45 second mixing period. The mixed material was then removed from the bowl, placed in a pan, and allowed to dry in an oven at 100 degrees Fahrenheit. The mixed material was stirred every hour in order to obtain uniform drying throughout the material. After the moisture content of the mix had been reduced to 1 per cent or less, the samples were molded.

The 150-200 penetration asphalt cement could not be effectively incorporated into the sand at room temperature and as a result the sand was heated to 200 degrees Fahrenheit prior to mixing. The hydrated lime was blended into the sand prior to heating. The asphalt cement was heated to a temperature of 275 degrees Fahrenheit. As soon as the sand had attained the desired temperature the material was taken from the oven and put in the bowl of the mixer. The

required quantity of asphalt cement was added to the sand and the mixer turned on. After one minute the mixer was stopped and the sides of the bowl scraped. The mixer was then turned on for one minute, after which time the mixed material was removed from the bowl and placed in a pan. The samples were molded when the temperature of the mix was between 100 and 150 degrees Fahrenheit.

Molding the Unconfined Compression Samples:

A diagram of the unconfined compression sample mold used in this investigation is shown in Plate 1. The mold with the collars attached was placed on the bottom plunger and the spacer inserted to keep the bottom of the mold 1.5 inches above the base plate on the bottom plunger. Approximately 200 grams of mix were placed in the mold and rodded five times. The mold was then filled and the top plunger inserted. The spacer was removed and the assembled mold was then transferred to the Tinius-Olsen testing machine where load was applied slowly until a pressure of 5000 pounds was exerted on the sample. This load was held constant for one minute and then released. The collars of the mold were removed and the sample was trimmed flush with each end of the mold. The sample was then extruded from the mold and weighed. The molded weights of all samples of the same series were generally within 5 grams of each other. Pictures of the molding and extrusion procedures are shown in Plate 1A.

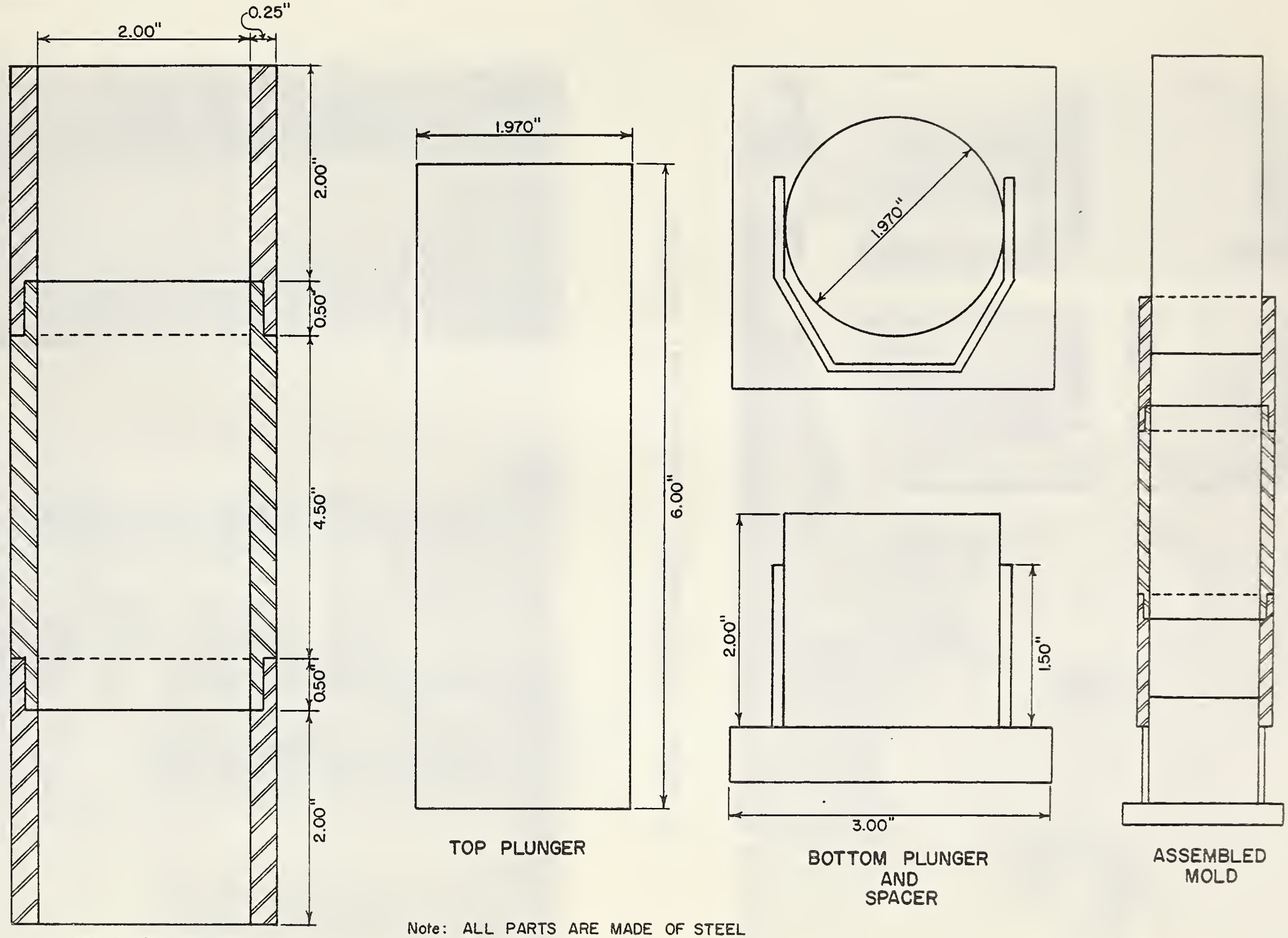
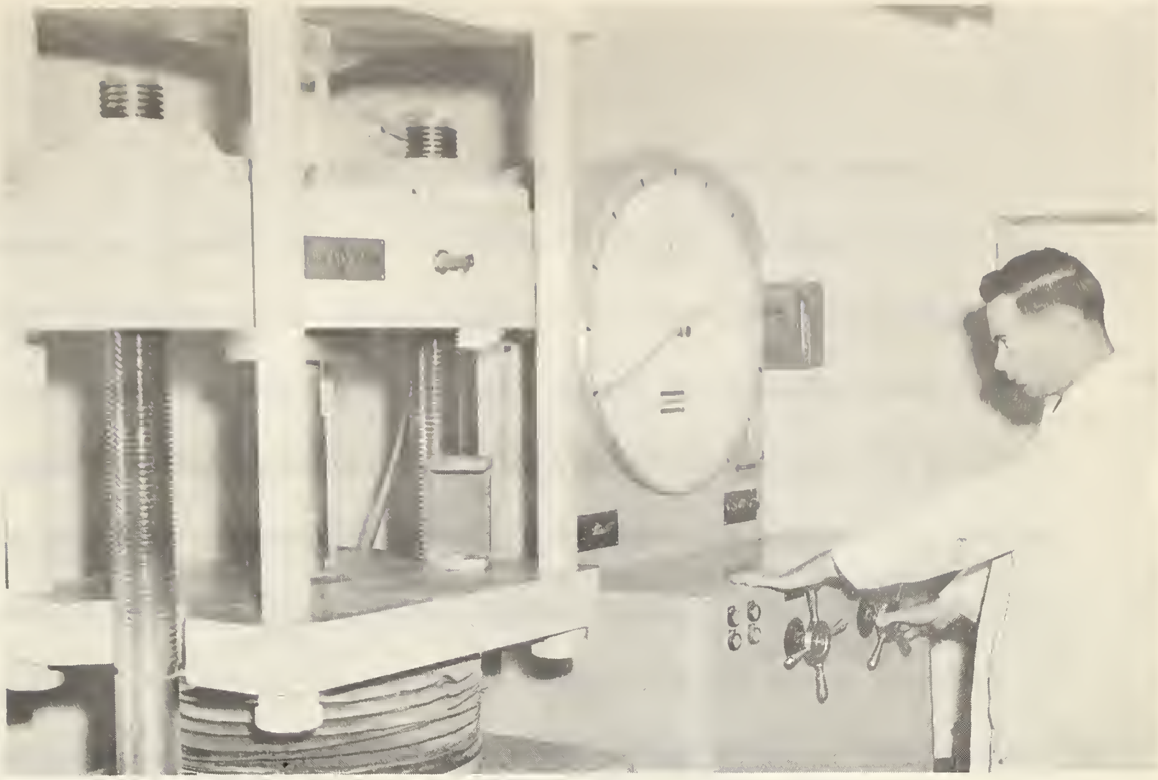
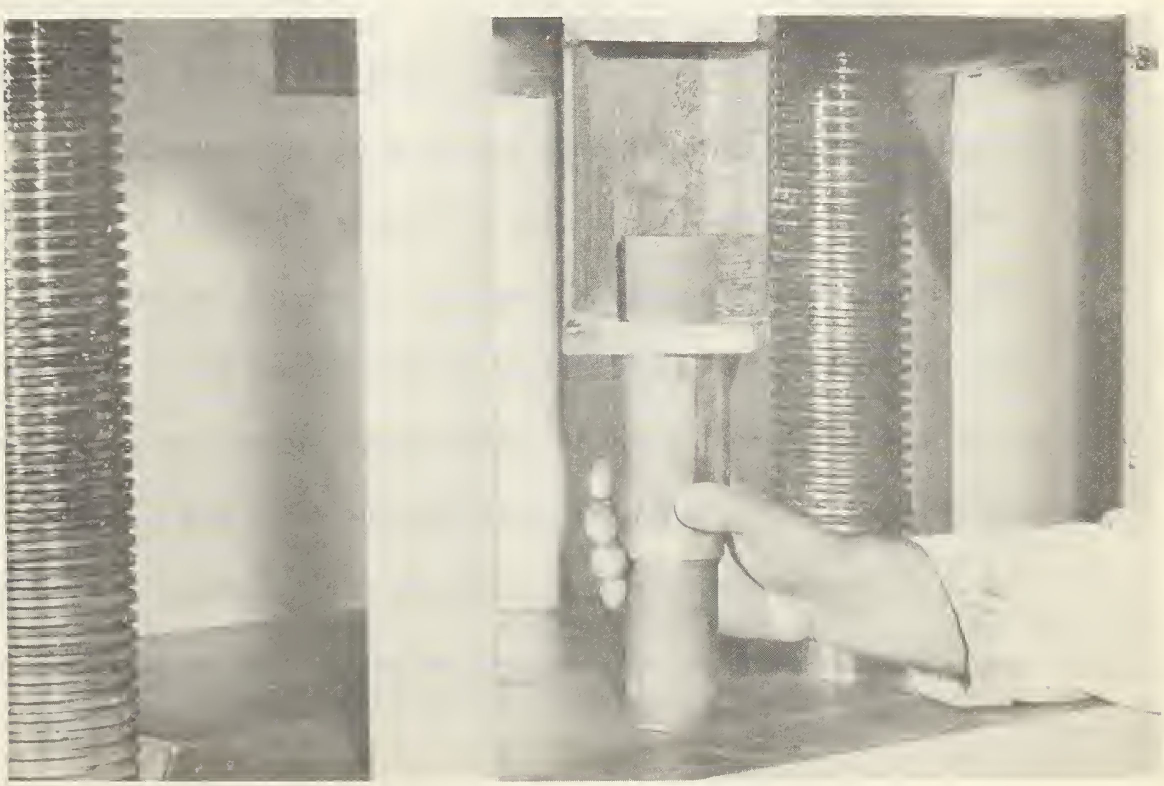


Plate 1: UNCONFINED COMPRESSION SAMPLE MOLD



MOLDING UNCONFINED COMPRESSION SAMPLES



EXTRUDING SAMPLE

Plate IA

The use of the double plunger was adopted in order to reduce the possibility of a variation in density throughout the 5-inch length of the sample. It was because of the possibility of this non-uniform density throughout the length of the sample with static compaction that some investigators preferred the use of a drop-hammer with compaction being accomplished in a number of layers. Samples made in this manner, however, have cleavage planes at the boundary of each lift that will affect the strength of the sample. If the length of the sample was cut down so that dynamic compaction could be accomplished in one lift, then the length would be so short as compared to the diameter that there would be end restraint developed in the breaking of the sample in compression.

Molding the Hubbard-Field Samples:

A diagram of the Hubbard-Field forming mold is shown in Plate 2. A 100 gram sample of the mix was placed in the mold and the plunger inserted. The mold was then transferred to the hydraulic press shown in Plate 2A and a load of 5000 pounds was applied to the sample, maintained for one minute, and then released. The sample was then removed from the mold. The length to diameter ratio of the sample is so small that there should be little or no variation in density within the length of the specimen.

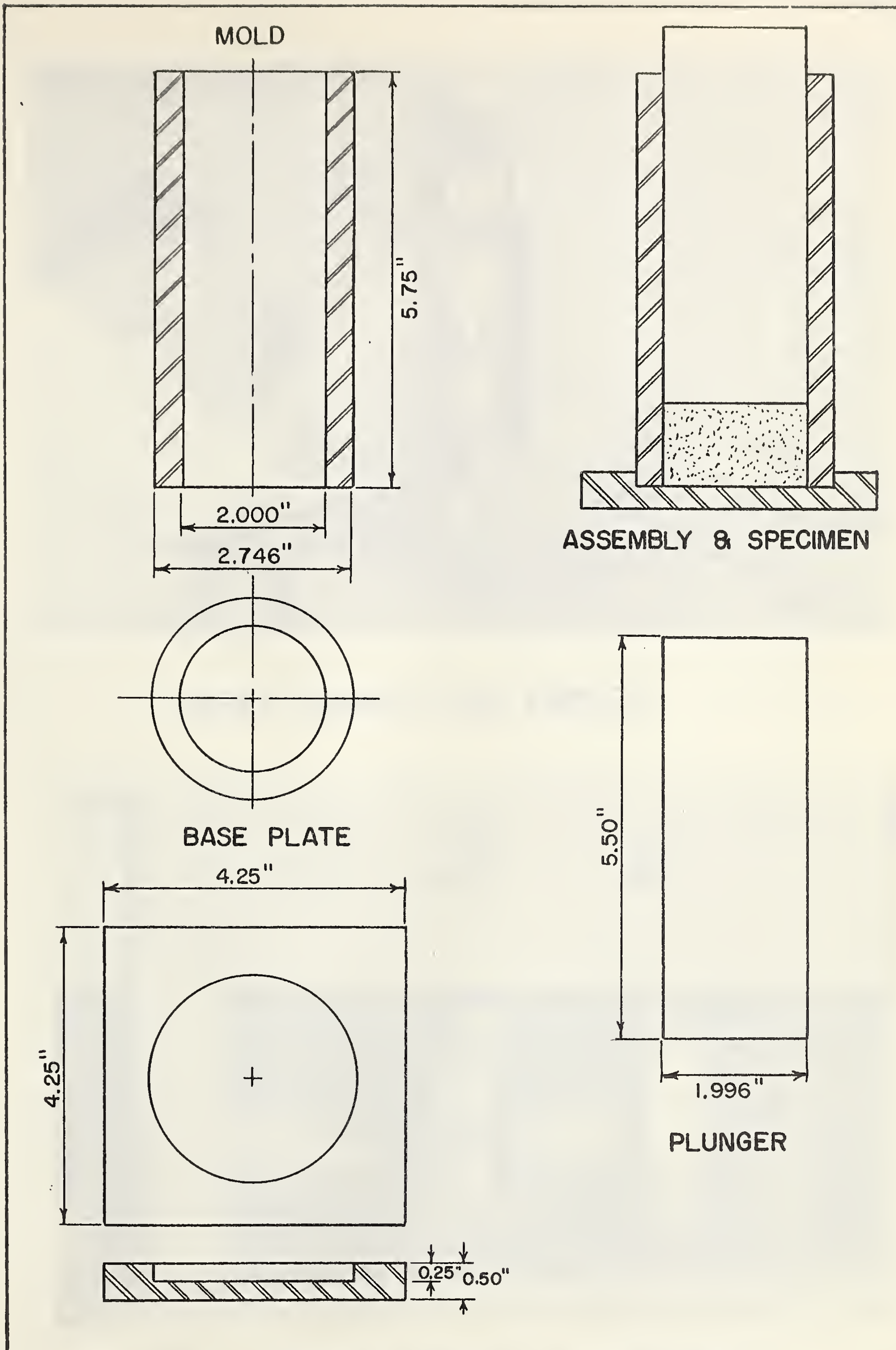
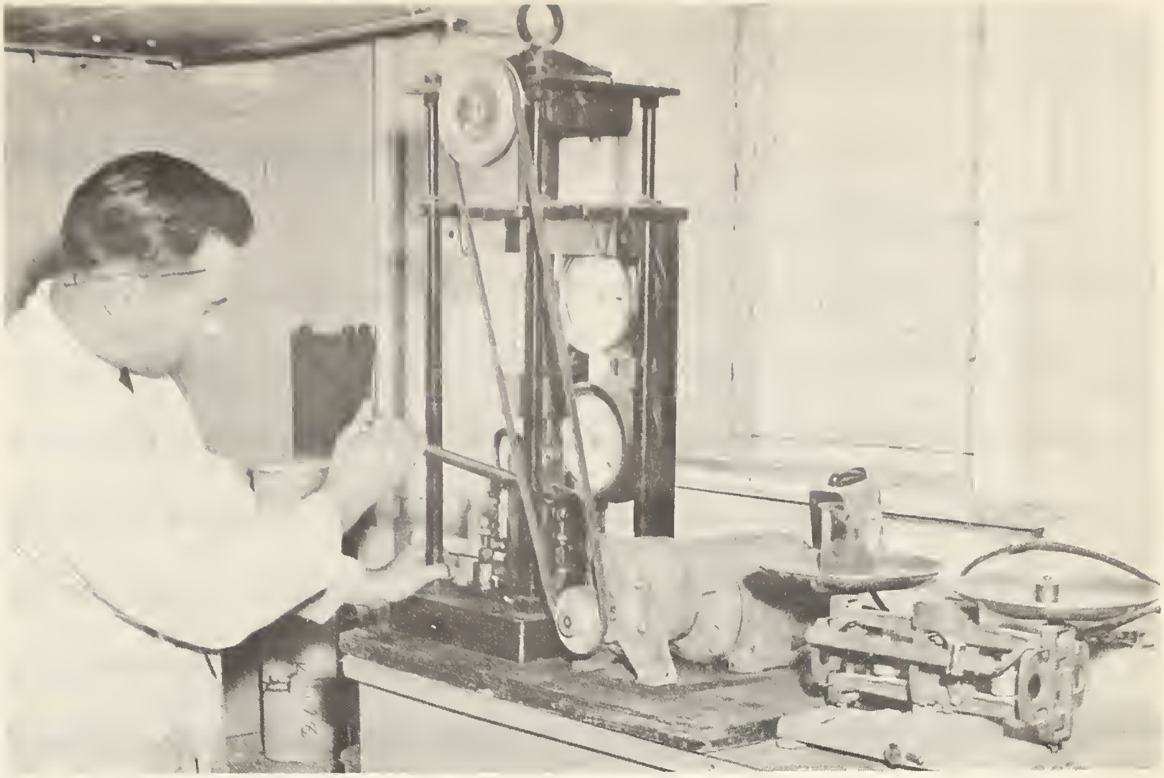
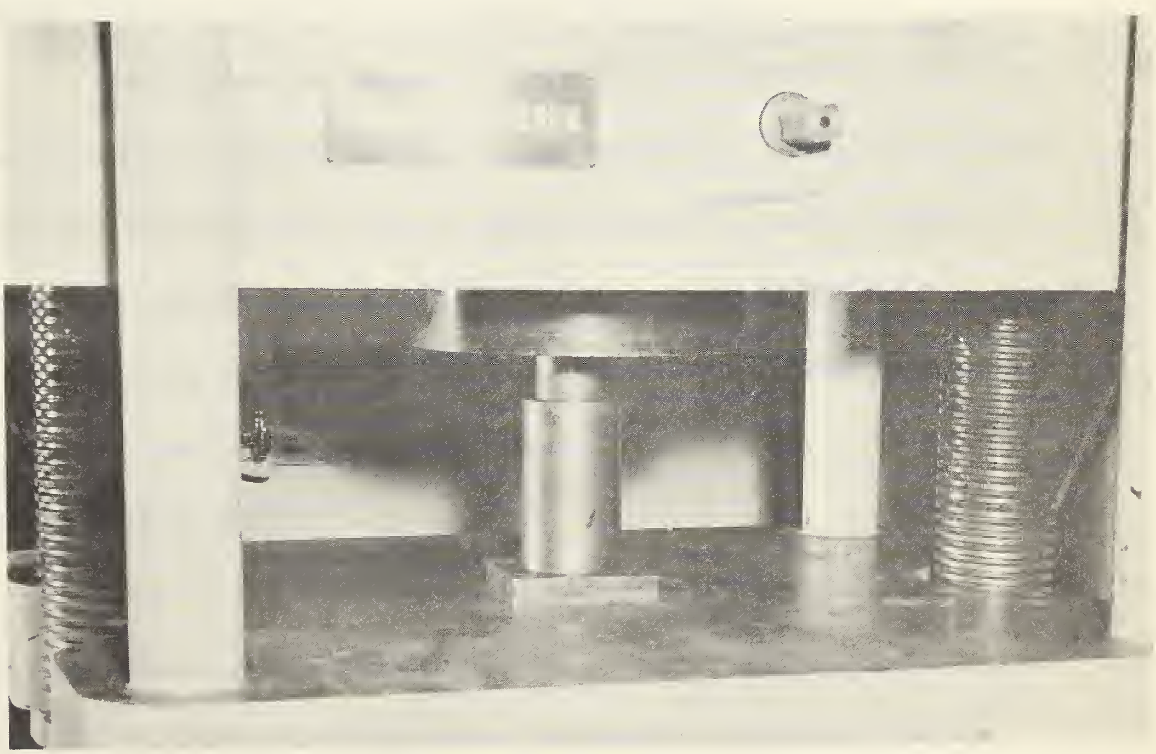


Plate 2: HUBBARD-FIELD FORMING MOLD



MOLDING HUBBARD - FIELD SAMPLES



TESTING HUBBARD - FIELD SAMPLES

Plate 2A

Modified Hubbard-Field Stability Test:

The apparatus used for testing the Hubbard-Field samples is shown in Plate 2A and Plate 3. Prior to testing each sample was weighed in air and in water in order to determine the volume and density of the briquette. The specimen was then placed in the testing mold and loaded at the rate of 0.1 inches per minute in the Tinius-Olsen testing machine. The maximum load in pounds that the sample could withstand was taken as the Modified Hubbard-Field Stability. The time in seconds from the start of application of the load until failure occurred was also recorded. This procedure differs from the original Hubbard-Field method in that testing was done at room temperature instead of 140 degrees Fahrenheit.

The apparatus shown in Plate 2A was used for testing the specimens in the field as well as for molding. One of the reasons this test was adopted by the Highways Branch of the Province of Manitoba was that the apparatus was readily portable and thus could be used in the field for job control as well as for preliminary investigations in the main laboratory.

Freeze-Thaw Test:

The freeze-thaw test used in this investigation was similar to the British freeze-thaw test.(25) In the British method, 2-inch by 4-inch specimens were placed in plastic containers and the

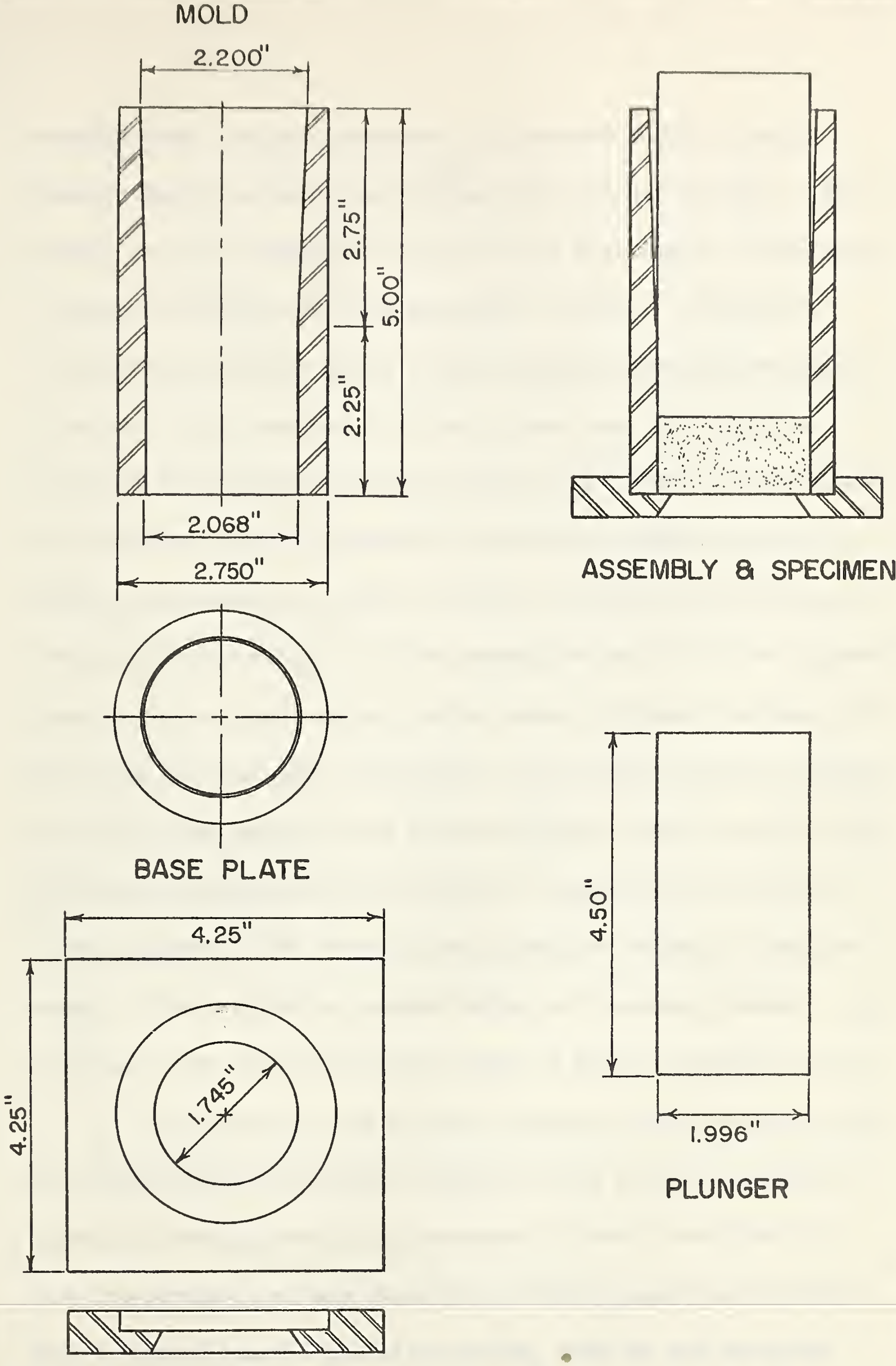
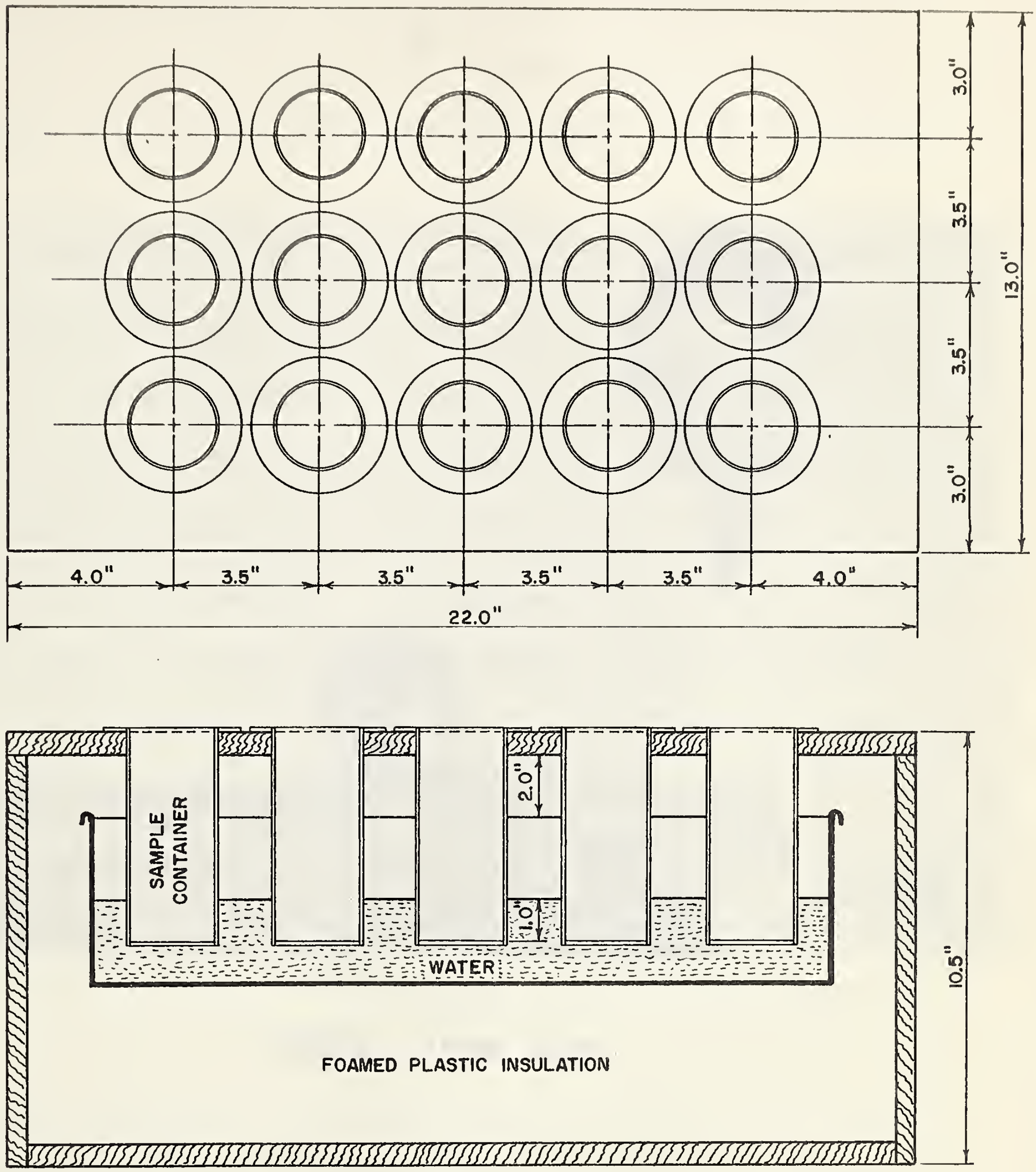


Plate 3: HUBBARD-FIELD TESTING MOLD

container and specimen inserted in a thermos bottle in such a manner that the sample was sitting in 0.25 inches of water. The sample was then subjected to 14 cycles of freezing for 16 hours at -5 degrees Centigrade and thawing for 8 hours at +25 degrees Centigrade. Iowa has used a similar method involving the use of 2-inch by 2-inch samples in order to determine the effects of cycles of freezing and thawing on soil-cement. (26) The University of Alberta has used an apparatus involving the same principle in order to determine the effect of cycles of freezing and thawing on 2-inch by 2-inch samples of lime stabilized soil. (22) This apparatus consisted of an insulated box with a number of plastic containers in which the soil samples were placed. In all three methods outlined, the sample was given access to water at the bottom while freezing took place from the top to the bottom. Depending on the nature of the material in the samples, water may be drawn up from the supply at the base of the sample during the freezing process, thus resulting in the formation of ice lenses in frost susceptible soils.

The apparatus used in this investigation was modeled after the British apparatus and the apparatus used at the University of Alberta. This apparatus is illustrated in Plate 4 and Plate 4A. The freeze-thaw box was made of half-inch plywood and insulated with a foamed plastic type of insulation, with the soil samples



Note: BOX MADE OF HALF INCH PLYWOOD
SAMPLE CONTAINERS MADE OF PLEXIGLASS

Plate 4: FREEZE-THAW BOX FOR UNCONFINED COMPRESSION SAMPLES

FREEZE - THAW BOX

Plate 4A

being held in plexiglas containers. These containers had holes in the bottoms in order to permit the water to come to a free water surface one inch above the base of the samples. The water supply was held in a metal tray inside the box.

All samples were subjected to 14 cycles of freezing and thawing. Each cycle lasted for 24 hours; 16 hours of which the samples were placed in the freeze-thaw box and put in the freezer at -8 degrees Centigrade. At the end of this 16 hour freezing period the box was removed from the freezer, the samples dried on the surface with a paper towel, and the weight of the samples recorded. The samples were then put back in the apparatus and allowed to stand at room temperature for 8 hours. Volume determinations were made on the samples at the start of the test, after 7 cycles, and at the end of the 14 cycles. At the end of the freeze-thaw period the samples were removed from the apparatus, placed in the air for 24 hours, and the unconfined compressive strengths determined.

There was little swelling or water absorption noticed on any of the samples, though those samples containing 2 per cent residual asphalt did show some signs of disintegration near the end of the curing period. It is hard to say whether this test accurately depicts a roadway condition or not, but as long as there are some samples that show signs of loss of material and some

samples that apparently are not affected by the test, then an evaluation of the various samples can be made.

Testing the Unconfined Compression Specimens:

The unconfined compression samples were tested by means of a Soiltest Model U-164 motorized unconfined compression apparatus as shown in Plate 5. The samples were tested at a constant rate of strain of 0.045 inches per minute. With all samples being 5 inches high, this was equivalent to a rate of strain of 0.9 per cent per minute. Load was measured by means of a double proving ring with a capacity of 125 pounds. The maximum unit stress that the sample could withstand was taken as the failure stress. The various charts used in the computations are included in Appendix "C".

An idea of the number of samples used in this investigation can be obtained from Plate 6. Each row of samples contains 9 specimens; 3 of which were broken after air curing, 3 others after 14 cycles of freezing and thawing, and the last 3 after water immersion.

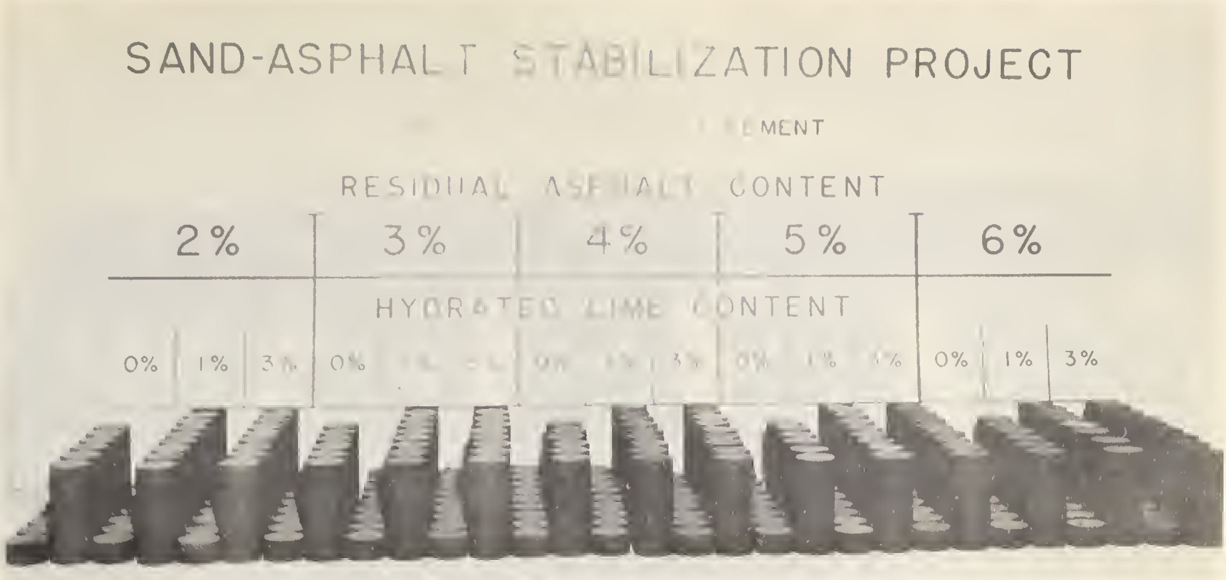
Water Immersion Test:

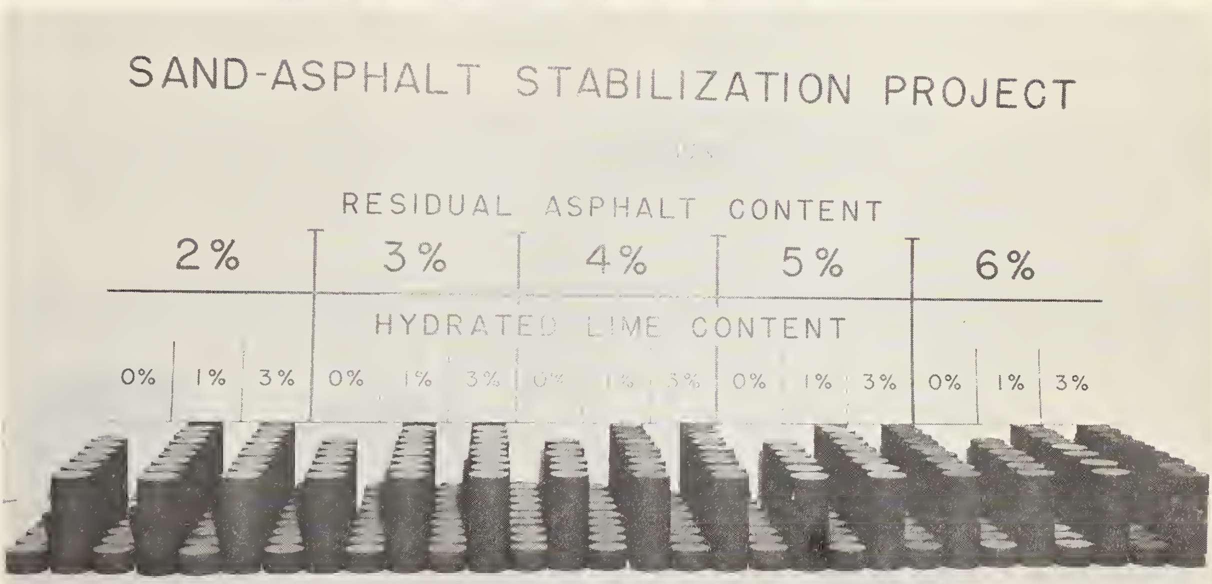
The unconfined compression samples and the Hubbard-Field samples were subjected to a complete water immersion period for 42 to 43 days. A photograph of the tank and the immersed specimens is shown in Plate 7. Periodic weight and volume measurements

UNCONFINED COMPRESSION TESTING

TYPICAL FAILURES

Plate 5



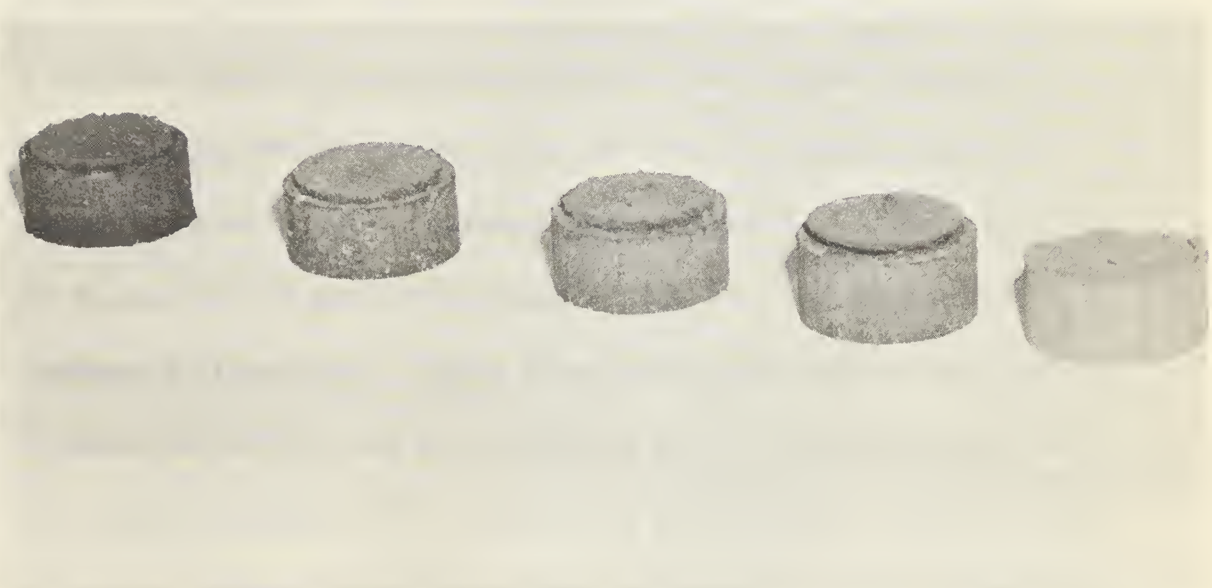


SOME OF THE SAMPLES USED IN THE INVESTIGATION

Plate 6

[illegible]

SAMPLES SUBJECTED TO WATER IMMERSION



TYPICAL HUBBARD-FIELD FAILURES

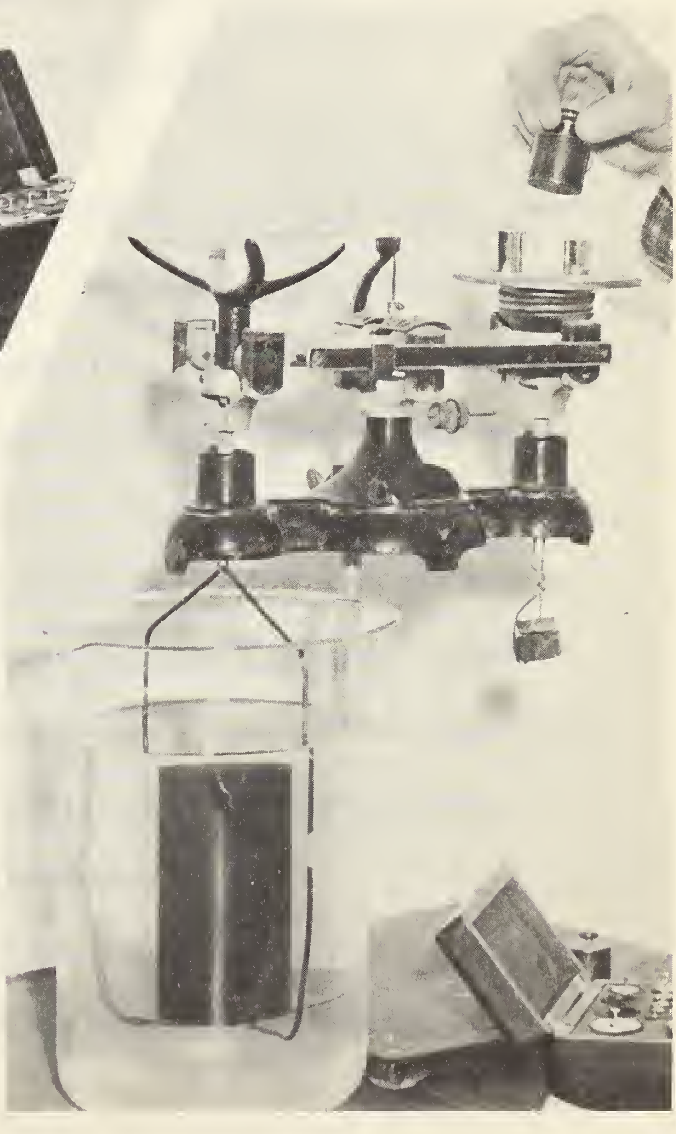
Plate 7

were taken on the unconfined compression samples to determine the extent of water absorption and swelling. The volume determinations were made as shown in Plate 8. Upon completion of the immersion period the samples were removed from the tank, dried on the surface with a paper towel, and tested immediately.

This water immersion period was not intended to depict a condition that is likely to occur in a roadbed. The samples were immersed completely in order to get a uniform degree of saturation throughout the specimen. The main purpose of the water immersion test was to determine the effect of hydrated lime and asphalt on the rate and amount of water absorption of the compacted specimens.

Effect of Molding Water Content on Strength and Density:

In order to determine the effect of the molding water content on the strength and density of the sand-emulsion mix containing 5 per cent residual asphalt, a number of mixes were made at an initial mixing water content of 14 per cent. A similar group of mixes were made up to contain 5 per cent residual asphalt from the SS-1 emulsion, 3 per cent hydrated lime, and a mixing water content of 17 per cent. These mixes were put in the oven at 100 degrees Fahrenheit and allowed to dry back to various water contents before molding. The mixes were stirred every hour in order to insure uniform drying throughout the sample. At each molding



VOLUME
DETERMINATION

Plate 8

water content three 2-inch by 5-inch samples were statically compacted with the Tinius-Olsen testing machine and one standard AASHO density determination was made. All samples were allowed to dry at room temperature until practically all the mixing water had been lost before being completely immersed in water for a period of 42 to 44 days. At the end of the immersion period the samples were removed from the tank, surface dried with a paper towel, and the unconfined compressive strength determined. The samples were then dried in the oven at 105 degrees Centigrade in order to determine the dry weight of the mix.

Triaxial Compression Tests:

All triaxial compression tests were run on 2-inch by 5-inch statically compacted specimens. The samples were made up to contain 5 per cent residual asphalt from the SS-1 emulsion. Mixes containing no hydrated lime were mixed at a water content of 14 per cent and those containing 3 per cent hydrated lime at a water content of 17 per cent. These mixes were allowed to dry back to a water content of less than 1 per cent before molding. After molding the samples were air dried for a period of two weeks and then immersed in water for a period of 44 days before being subjected to the triaxial compression test.

The confining pressure was applied to the sample by means of air pressure over water. Load was applied by means of a

Farnell compression machine at a constant rate of strain and measured on a 400 pound proving ring. The rates of strain used were 0.011, 0.037, and 0.055 inches per minute. At each rate of strain, samples were run at confining pressures of 10, 20, 30, 40, and 50 pounds per square inch. Drainage of the sample from the bottom base plate was permitted during the test.

CHAPTER VI

DISCUSSION OF TEST RESULTS

Classification of Soil:

The material used in this investigation was a fine, clean, poorly graded sand. The soil was non-plastic in nature with about 3 per cent of the particles finer than the No. 200 sieve. According to the AASHO Soil Classification system this material would be of the A-3 type. Because of the poor gradation of the sand particles, it would fall into the SP group of the Unified Soil Classification system. A standard AASHO compaction test indicated that the maximum dry density of the soil was 103 pounds per cubic foot at an optimum moisture content of 14.0 per cent.

The results of the drained triaxial test run on the sand are shown in Appendix "B". The Mohr envelope shown in Figure 1 indicates that the sand had an angle of internal friction of 31 degrees and a unit cohesion of 1.5 pounds per square inch. The average moisture content of the samples used for the triaxial test ranged from 8 to 10 per cent, with the result that the average dry density of the samples was only 92.8 pounds per cubic foot. The stress-strain curves for the triaxial test are illustrated in Figure 2. There was no distinct failure point on the stress-strain curve for any of the samples and as a result all stress computations for the Mohr

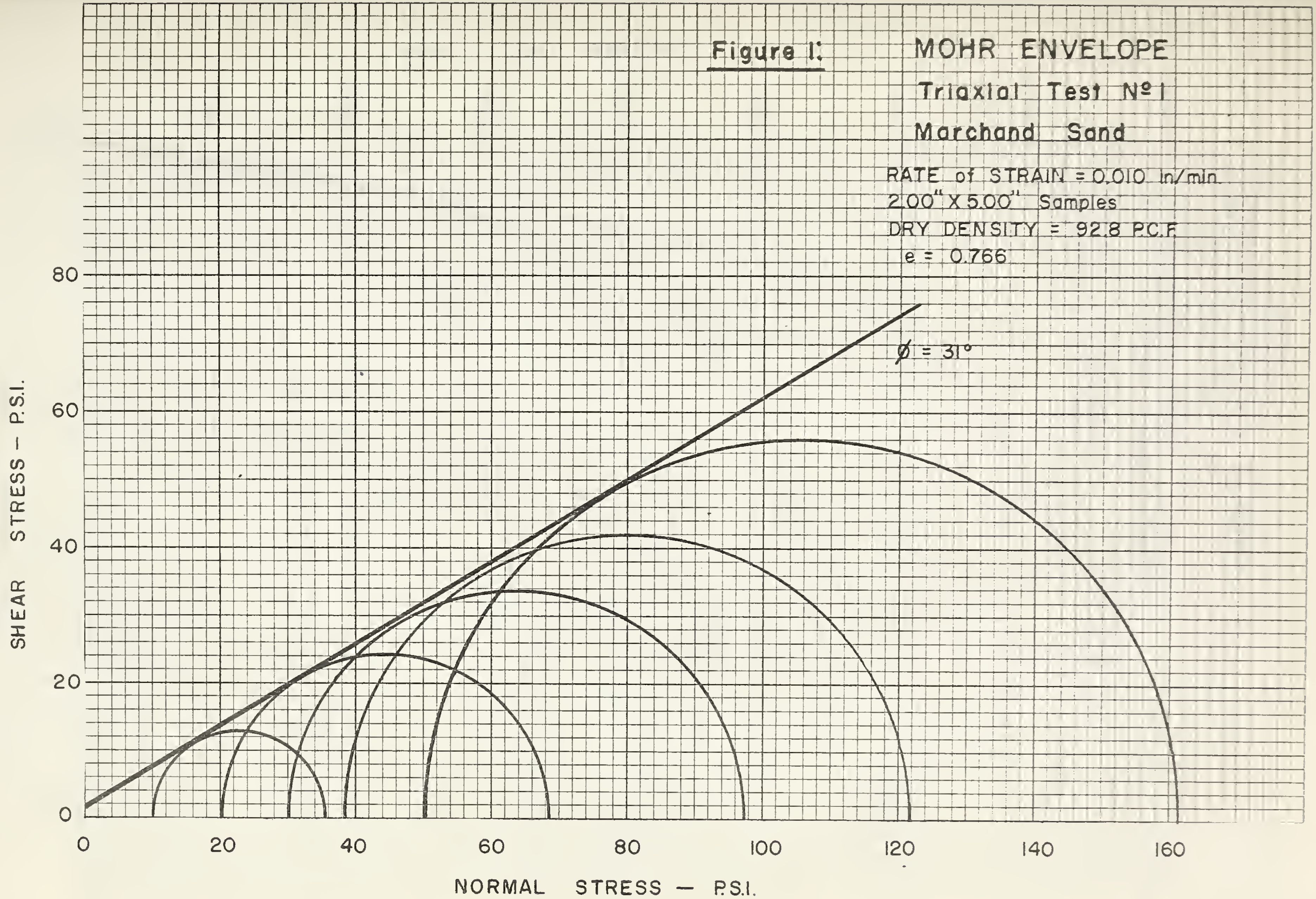


Figure I:
MOHR ENVELOPE
Triaxial Test Nº I
Marchand Sand
RATE of STRAIN = 0.010 in/min
2.00" X 5.00" Samples
DRY DENSITY = 92.8 P.C.F.
e = 0.766
ϕ = 31°
SHEAR STRESS — P.S.I.
NORMAL STRESS — P.S.I.
0
20
40
60
80
100
120
140
160

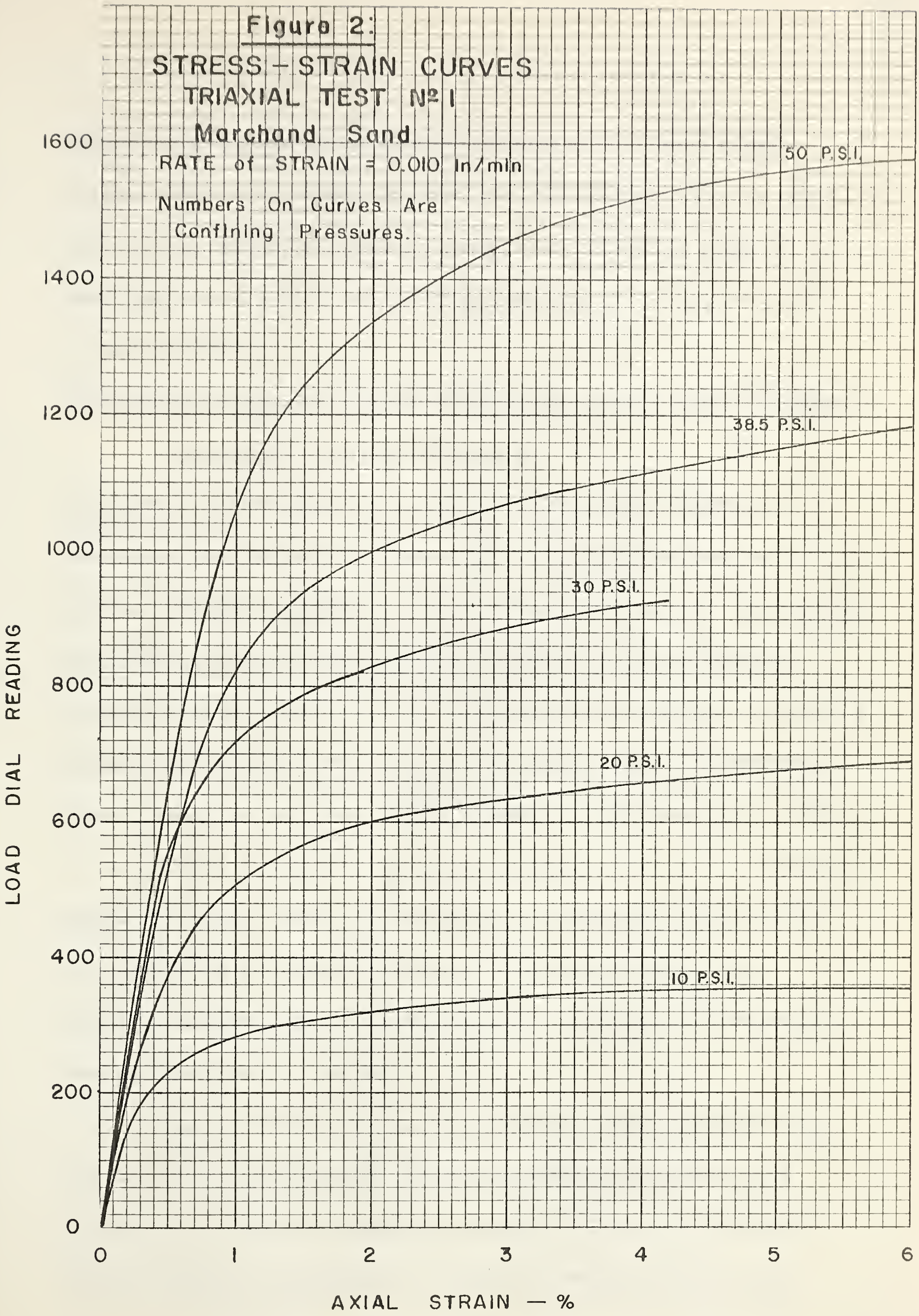


Figure 2:
STRESS - STRAIN CURVES
TRIAXIAL TEST № 1
Marchand Sand
RATE of STRAIN = 0.010 in/min
Numbers On Curves Are Confining Pressures.
50 P.S.I.
38.5 P.S.I.
30 P.S.I.
20 P.S.I.
10 P.S.I.
LOAD DIAL READING
AXIAL STRAIN — %
0
200
400
600
800
1000
1200
1400
1600
1
2
3
4
5
6

envelope were based on an assumed failure at 4 per cent strain. Although this strain is greater than the deformation occurring when a truck axle passes over the pavement, it is within the range of deformations occurring when rutting begins to be noticeable in the pavement surface.

Unconfined Compression Tests on Sand-Penetration Asphalt Samples:*

Unconfined Compressive Strength: The results of the unconfined compression tests run on the sand-asphalt samples containing the 150-200 penetration grade of asphalt cement and various amounts of hydrated lime are shown in Figure 3. Figure 3(a) indicates that there was very little difference in the unconfined compressive strength of the air cured samples containing no hydrated lime as compared to those samples containing 1 per cent hydrated lime. Also, for these two series of tests, there appears to be very little variation in the unconfined compressive strength with different asphalt contents. There is, however, a considerable increase in strength for those samples containg 3 per cent hydrated lime. Here again there appears to be no definite variation in strength with the various asphalt contents.

Figures 3(b) and 3(c) show the effect of lime and asphalt on the unconfined compressive strength of samples subjected to 14 cycles of freezing and thawing and samples subjected to complete water immersion respectively. Generally there seems to be an

* All mix properties are the average of three specimens

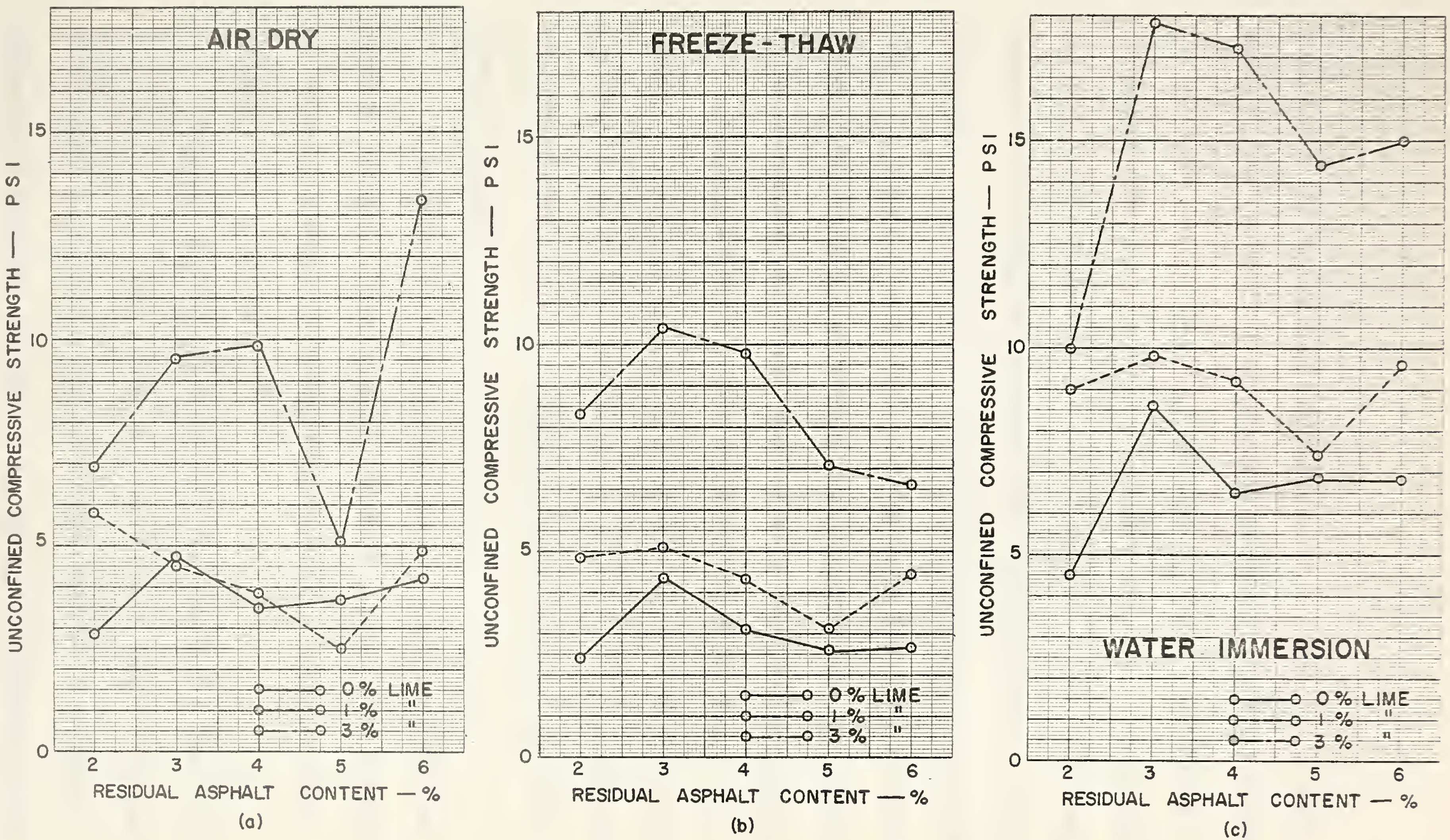


Figure 3: EFFECT OF LIME AND ASPHALT ON UNCONFINED COMPRESSIVE STRENGTH FOR AIR DRY, FREEZE - THAW, AND WATER IMMERSION CURING PERIODS.

150-200 PEN. A.C.

increase in the strength of the samples when subjected to either of these curing periods. This increase in strength is more pronounced for those samples containing 3 per cent hydrated lime than for those samples containing 0 or 1 per cent hydrated lime. All compacted samples were allowed to cure for a period of at least two months in the air before being subjected to either the freeze-thaw or water immersion curing periods. The samples contained no water at the time of mixing and as a result the cementing effect of the lime may not have had a chance to develop until the specimens were given access to water in either the freeze-thaw or water immersion curing periods. For samples containg 3 per cent hydrated lime and 4 per cent asphalt cement, the unconfined compressive strength of the specimens subjected to 42 days water immersion is about 170 per cent of the unconfined compressive strength of similar samples that were broken after air curing.

In general there is not much change in strength with various asphalt contents. There appears, however, to be quite a definite increase in strength resulting from the addition of 3 per cent hydrated lime to the mix.

Molded Dry Density: Figure 4 illustrates the effect of lime and asphalt on the molded dry density of the unconfined compression samples subjected to the various curing periods. The data in Appendix D indicates that the volume change of the sample due to

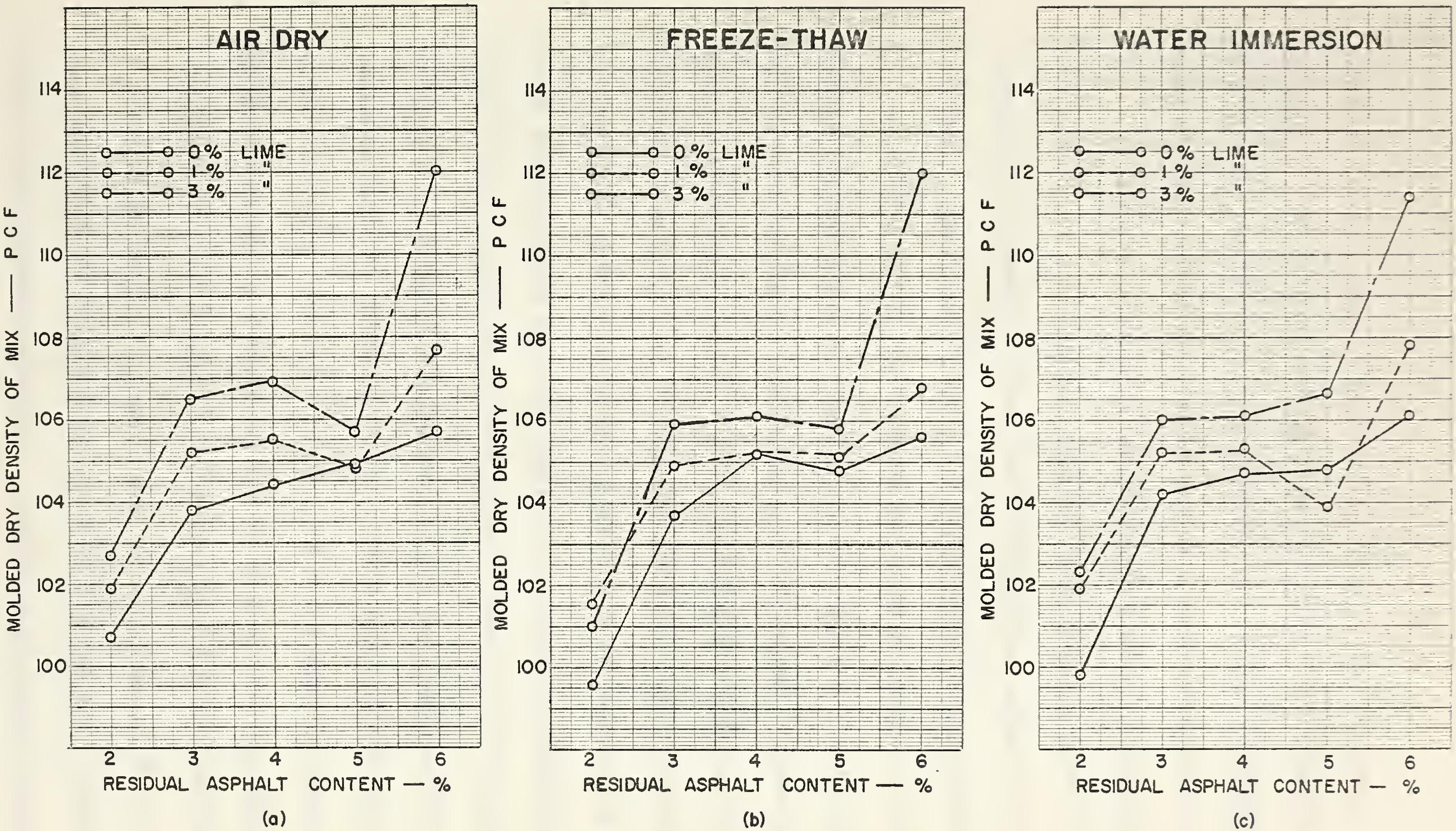


Figure 4: EFFECT OF ASPHALT AND LIME ON THE MOLDED DRY DENSITY OF 2.0" x 5.0" UNCONFINED COMPRESSION SAMPLES SUBJECTED TO AIR DRY, FREEZE-THAW, AND WATER IMMERSION CURING PERIODS.

150—200 PEN. A.C.

either the freeze-thaw or water immersion curing periods is negligible. Since there is very little variation in the molded weight of any of the samples of a given series, the molded dry density of the samples subjected to the various curing periods changes very little.

Figure 4 indicates there is quite a sharp increase in density from 2 to 3 per cent residual asphalt. The dry density of the mix remains fairly constant from 3 to 4 to 5 per cent asphalt, and then increases rather sharply from 5 to 6 per cent. It is believed that the explanation of this non-uniform increase in density with increasing asphalt content lies in the field of the soil physicist, and no attempt will be made to explain the variation in this report. There was a general increase in density with the addition of 1 and 3 per cent hydrated lime to the mix. Assuming the lime to act as a filler and occupy space in the voids in the aggregate, then, based on a 400 gram sample of dry soil, the addition of 1 per cent hydrated lime should cause an increase in dry density of the mix of 1.0 pounds per cubic foot. Similarly the addition of 3 per cent hydrated lime should cause an increase in the dry density of the mix of 2.9 pounds per cubic foot. The results of the analysis of the samples show that the general increase in dry density for increasing lime contents does not follow exactly the 1 pound per cubic foot increase expected for each 1 per cent addition of hydrated lime. It would appear that the lime has not caused an agglomeration of the soil particles. If there had been a flocculation of particles, a decrease in density should occur.

It is possible that the addition of the hydrated lime to the sand accomplishes a twofold purpose of filling the voids and binding some of the smaller particles together.

Void Content of Mix: Figure 5 shows the effect of hydrated lime and asphalt on the percentage of void space in the mix for the samples subjected to the various curing periods. Again, since there is very little change in the volume of the sample during any of the curing periods, there is very little difference in the shapes of the curves in Figures 5(a), 5(b), and 5(c). All curves indicate a decrease in the percentage of void space in the mix with increasing percentages of asphalt. The void content of the mix drops about 8 per cent when the asphalt content is increased from 2 to 6 per cent. There is also a decrease in the void content of the mix with the addition of the hydrated lime, indicating that hydrated lime and asphalt are both beneficial in reducing the void content of the mix. These curves follow a somewhat similar pattern to the density curves in that there is a considerable decrease in the void content of the mix from 2 to 3 per cent asphalt. The effect of the asphalt in decreasing the void content of the mix is then reduced somewhat for samples with 3, 4, and 5 per cent asphalt; but then increases from 5 to 6 per cent asphalt.

Per Cent Voids Filled After Immersion: Figure 6(b) indicates the effect of hydrated lime and asphalt on the percentage of the void

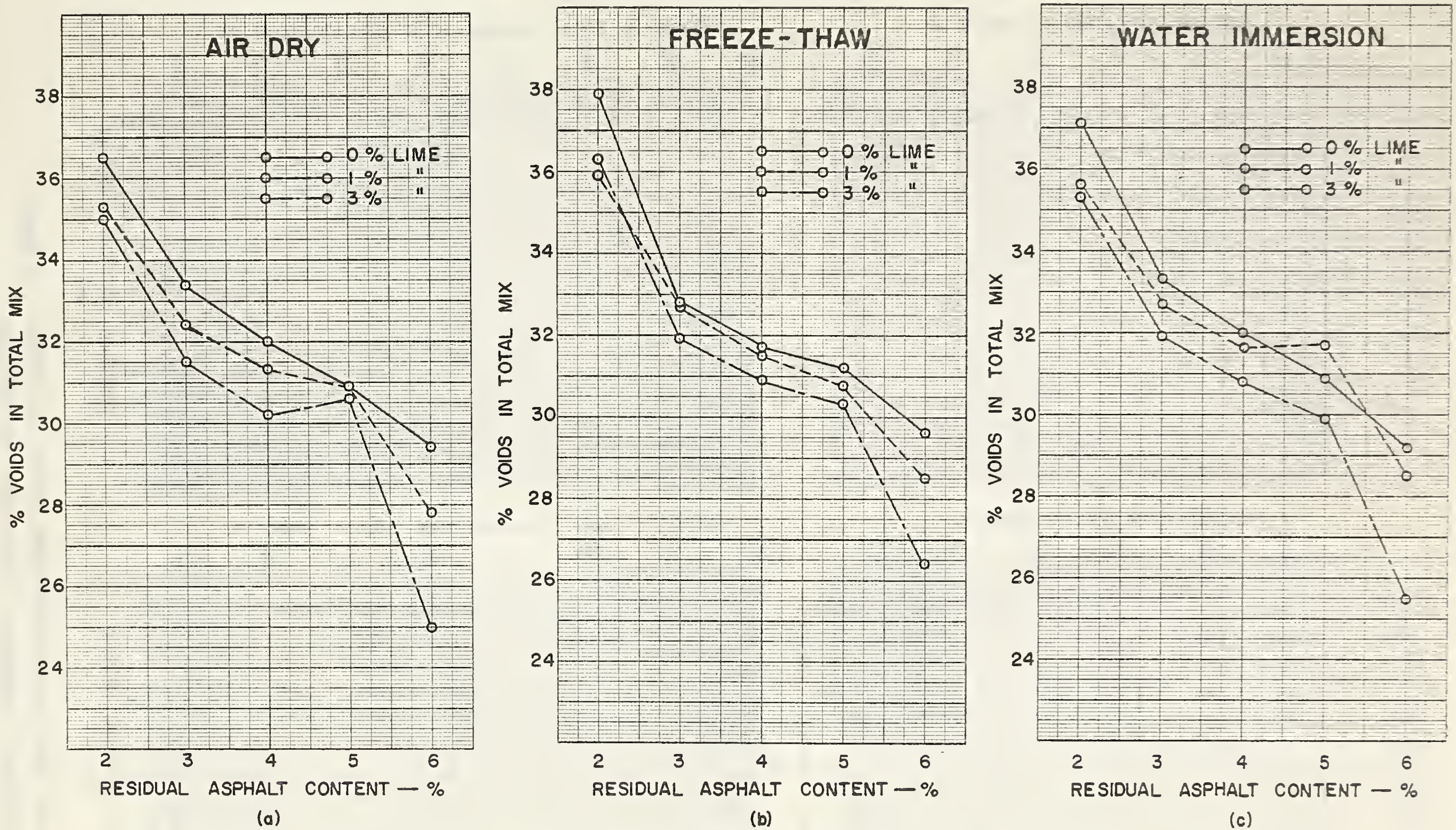


Figure 5: EFFECT OF ASPHALT AND LIME ON THE VOID CONTENT OF THE MIX FOR 2.0" x 5.0" UNCONFINED COMPRESSION SAMPLES SUBJECTED TO AIR DRY, FREEZE-THAW, AND WATER IMMERSION CURING PERIODS.

150-200 PEN. A.C.

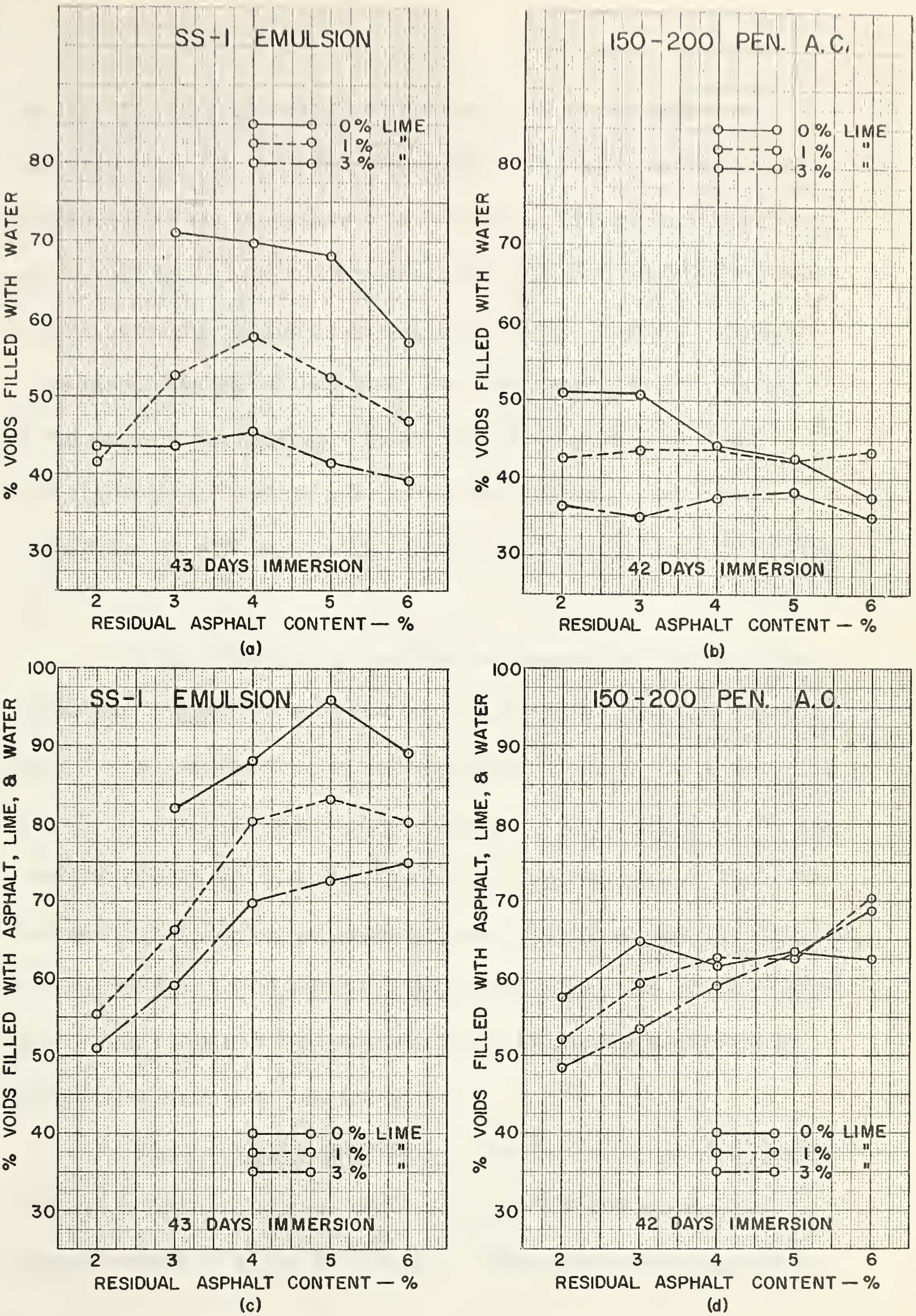


Figure 6: EFFECT OF WATER IMMERSION ON VOIDS FOR VARIOUS LIME AND ASPHALT CONTENTS. — UNCONFINED COMPRESSION SAMPLES.

space in the aggregate filled with water after the 42 day water immersion period. For those samples containing 1 and 3 per cent hydrated lime there appears to be very little change in the percentage of void space in the aggregate filled with water for the various asphalt contents ranging from 2 to 6 per cent. However, samples containing no hydrated lime and 2 per cent asphalt had 51 per cent of the voids in the aggregate filled with water at the end of the immersion period whereas the samples containing 6 per cent asphalt had only 38 per cent of the voids in the aggregate filled with water.

Figure 6(d) shows the effect of asphalt and hydrated lime on the percentage of void space in the aggregate filled with asphalt, lime, and water after the 42 day immersion period. This plot gives an indication of the amount of void space left in the sample after the immersion period. The void space in the aggregate after immersion decreased with increasing asphalt content for those samples containing 1 and 3 per cent hydrated lime. The void space in the samples after immersion remained fairly constant for all asphalt contents when no hydrated lime was used in the mix.

Rate of Water Absorption: The rate of water absorption of samples containing various percentages of 150-200 penetration asphalt cement is shown in Figure 7. Water absorption appears to

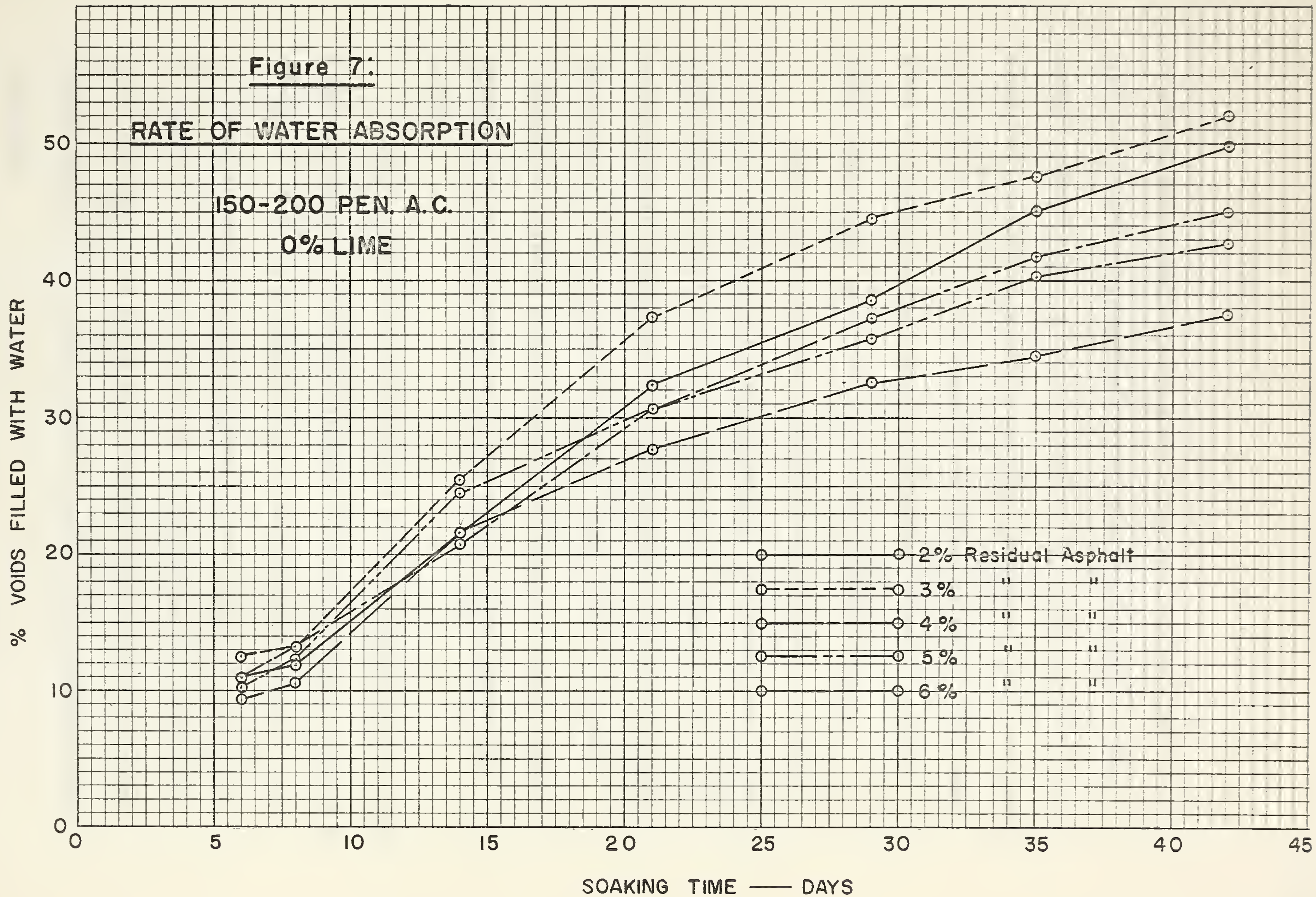


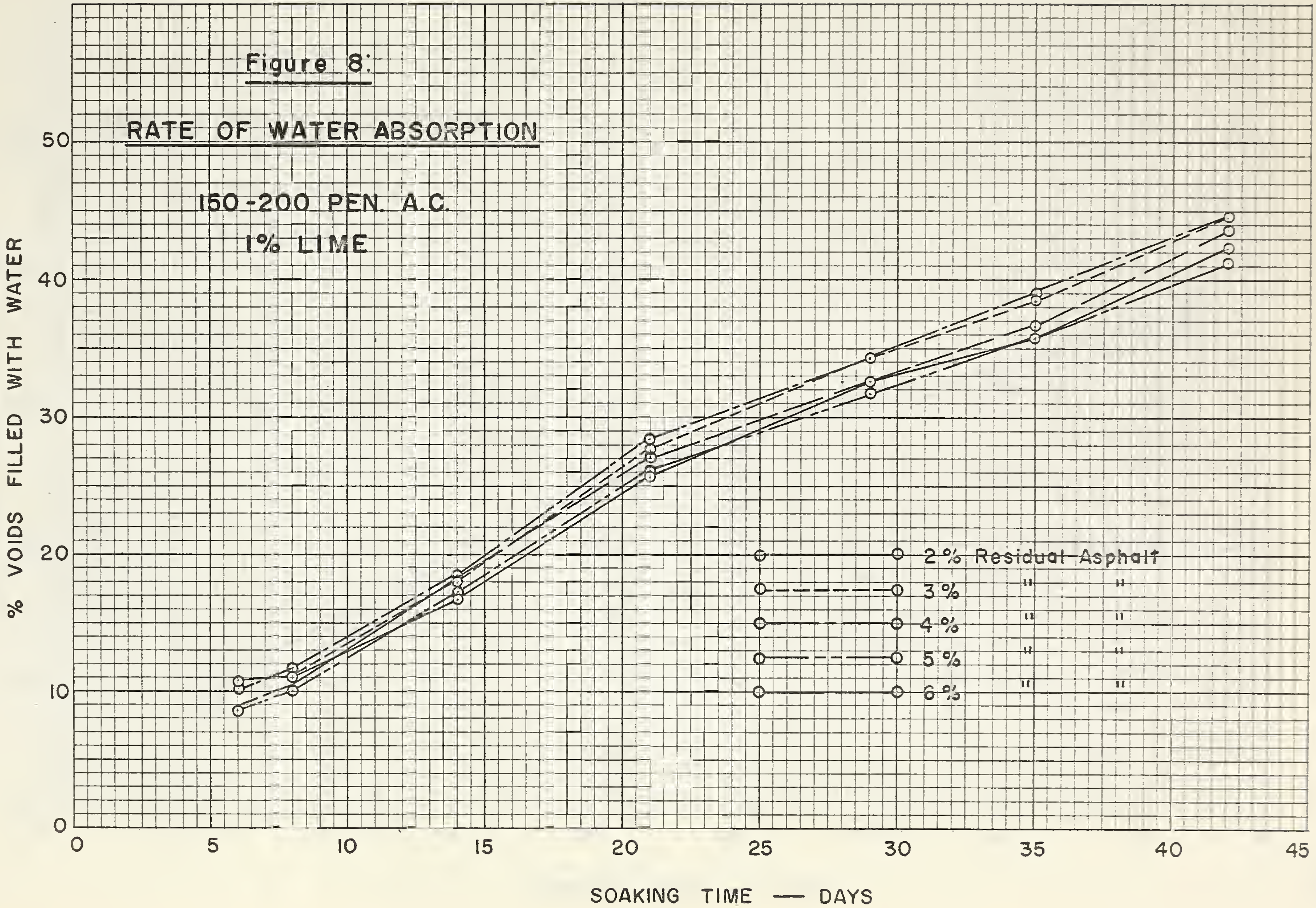
Figure 7:
RATE OF WATER ABSORPTION
150-200 PEN. A.C.
0% LIME
2% Residual Asphalt
3% " "
4% " "
5% " "
6% " "
% VOIDS FILLED WITH WATER
SOAKING TIME —— DAYS
0
5
10
15
20
25
30
35
40
45
50

be quite rapid during the first 15 to 20 days of the immersion period, with this rate decreasing slightly with further immersion. The asphalt cement appears to have some effect on the amount of water absorbed into the sample since samples containing 2 per cent asphalt had 50 per cent of the void space in the aggregate filled with water after 42 days immersion while the samples containg 6 per cent asphalt had only 37 per cent of the voids filled with water.

Figure 8 is a similar plot of the rate of water absorption of samples containing various percentages of 150-200 penetration asphalt cement and 1 per cent hydrated lime. The plot indicates that the asphalt content had very little effect on the rate of water absorption of the compacted mixtures. Samples at all asphalt contents had between 41 and 45 per cent of the void space in the aggregate filled with water at the end of the 42 day immersion period.

The rate of water absorption of samples containing 3 per cent hydrated lime and varying percentages of asphalt cement is shown in Figure 9. With the addition of 3 per cent hydrated lime to the mix, the residual asphalt content appeared to have very little effect on the degree to which the voids in the aggregate became filled with water. At the end of the 42 day immersion period all samples had between 35 and 38 per cent of the void space in the aggregate filled with water.

Figure 8:


RATE OF WATER ABSORPTION
150-200 PEN. A.C.
1% LIME
% VOIDS FILLED WITH WATER
SOAKING TIME — DAYS
0
10
20
30
40
50
5
15
25
35
45
2 % Residual Asphalt
3 % " "
4 % " "
5 % " "
6 % " "

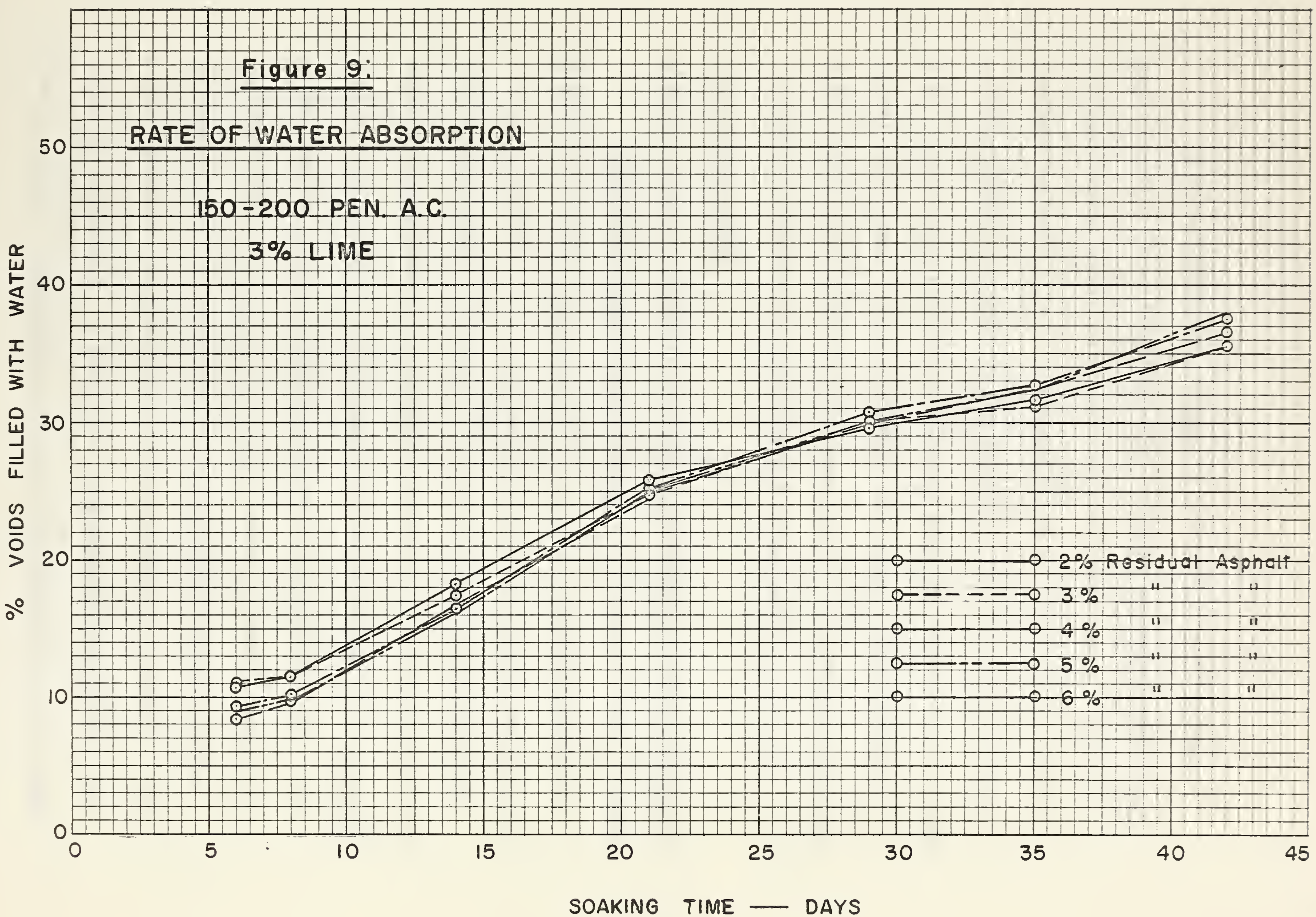


Figure 9.
RATE OF WATER ABSORPTION
150-200 PEN. A.C.
3% LIME
2% Residual Asphalt
3% " "
4% " "
5% " "
6% " "
% VOIDS FILLED WITH WATER
SOAKING TIME —— DAYS
0
10
20
30
40
50
5
15
25
35
45

It appears that the addition of hydrated lime to the sand-asphalt mix reduces the effect of the asphalt content on the amount of water that is absorbed by the compacted mix at any given time. Samples containing 5 per cent asphalt and no hydrated lime had 43 per cent of the void space in the aggregate filled with water after the 42 day immersion period. Similar samples containing 1 per cent hydrated lime had 41 per cent of the void space in the aggregate filled with water, while samples containing 3 per cent hydrated lime had 38 per cent of the voids filled with water after the complete immersion period.

Modified Hubbard-Field Tests on Sand-Penetration Asphalt Samples:

Modified Hubbard-Field Stability: The results of the Modified Hubbard-Field Stability tests run on samples containing various amounts of hydrated lime and asphalt cement are shown in Figure 10. Figure 10(a) shows the effect of lime and asphalt on the Modified Hubbard-Field Stability of samples that were air dried at room temperature before testing. There was very little change in the strength of the samples with the addition of 1 per cent hydrated lime. There appeared to be an increase in strength when the asphalt content was increased from 2 to 3 per cent, but the strength seemed to drop slightly when the asphalt content was increased to 4 per cent. The samples containing 4, 5, and 6 per cent asphalt all had about the same strength. The addition of 3 per cent hydrated lime increased

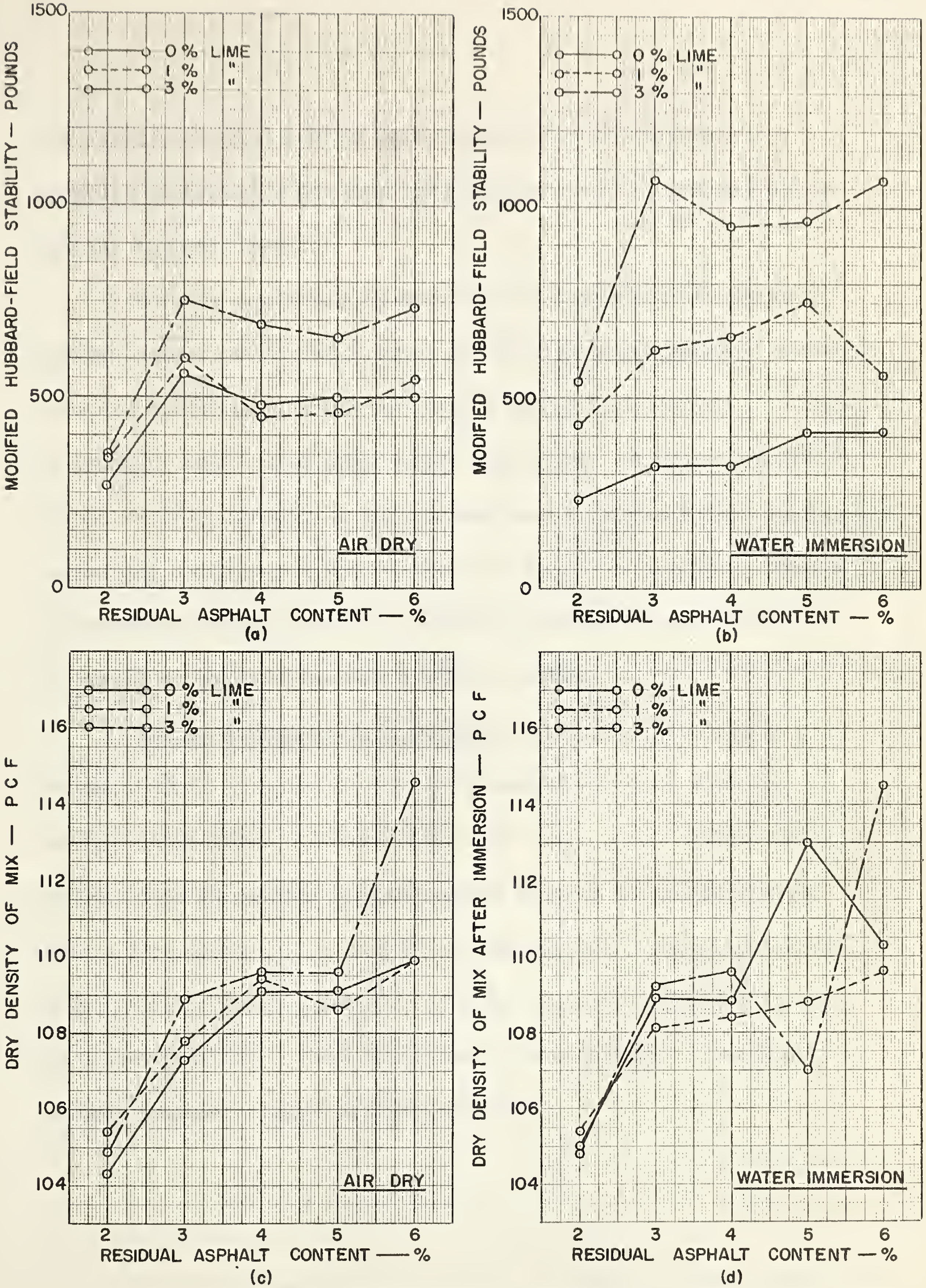


Figure 10: EFFECT OF ASPHALT AND LIME ON DENSITY AND HUBBARD-FIELD STABILITY —— 150-200 PEN. A.C.

the Modified Hubbard-Field Stability by 150 - 200 pounds. The samples containing 3 per cent hydrated lime and 3 per cent asphalt had the highest strength.

Samples containing no hydrated lime showed a decrease in strength when immersed in water for 42 days before testing, whereas samples containing 1 and 3 per cent hydrated lime showed an increase in strength when tested after water immersion. A maximum Modified Hubbard-Field Stability of 1070 pounds was recorded for the specimens containing 3 per cent hydrated lime and 3 per cent asphalt. This is an increase of 320 pounds over similar specimens that were dried in the air at room temperature before testing.

Molded Hubbard-Field Density: The dry density of the Hubbard-Field samples showed the greatest increase when the asphalt content was increased from 2 to 3 per cent. The increase in density with increasing asphalt content was not so pronounced for samples containing 4, 5, and 6 per cent asphalt. One exception to this general relation appeared to be the samples containing 3 per cent hydrated lime. Here there was a considerable increase in density between 5 and 6 per cent asphalt.

Unconfined Compression Tests on Sand-Emulsion Samples:

Unconfined Compressive Strength: The effect of residual asphalt content* and hydrated lime content on the unconfined compressive strength of 2-inch by 5-inch statically compacted specimens subjected to air dry, freeze-thaw, and water immersion curing periods is shown in Figure 11. Samples containing no hydrated lime and 3, 4, 5, and 6 per cent residual asphalt had unconfined compressive strengths ranging from 3.5 to 4.7 pounds per square inch when tested after air curing at room temperature. The samples containing 2 per cent residual asphalt had an average unconfined compressive strength of 8.3 pounds per square inch. This particular mix appeared quite dry and in order to form the samples, about 4 per cent water was added to the mix prior to molding. This water was then lost from the samples before testing. This drying out of the sample quite probably caused the unusually high strength at 2 per cent residual asphalt. Samples containing 1 per cent hydrated lime had unconfined compressive strengths ranging from 6.3 to 6.8 pounds per square inch, whereas samples subjected to the same air drying, but containing 3 per cent hydrated lime had a maximum unconfined compressive strength of 19.6 pounds per square inch at a residual asphalt content of 4 per cent.

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* Residual asphalt content refers to the percentage of asphalt cement in the specimen, based on the dry weight of soil.

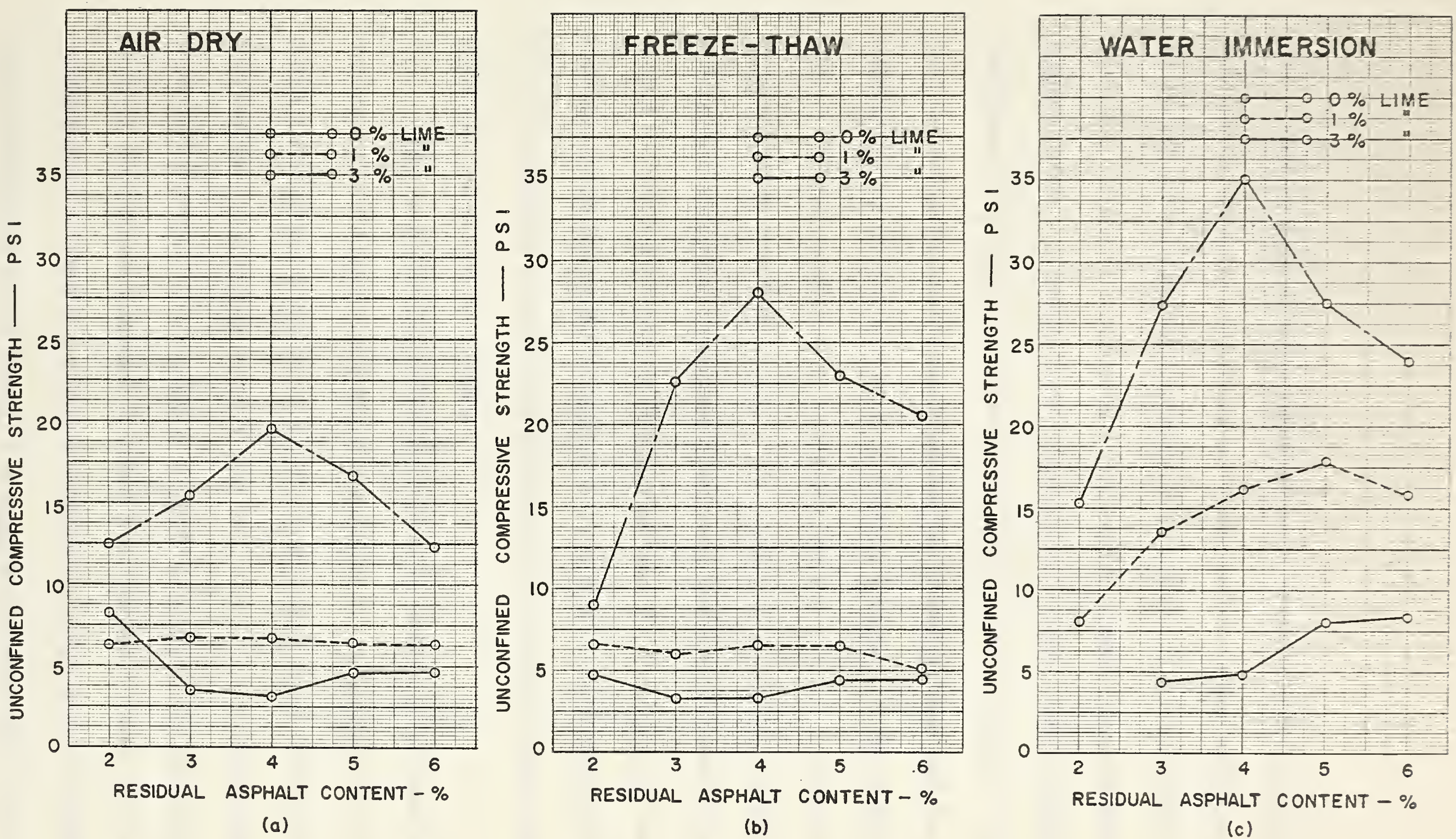

Figure 11: EFFECT OF ASPHALT AND LIME ON UNCONFINED COMPRESSIVE STRENGTH FOR AIR DRY, WATER IMMERSION, AND FREEZE - THAW CURING PERIODS.

SS-1 EMULSION

There was no apparent difference in the unconfined compressive strength of samples containing no hydrated lime when subjected to the 14 cycles of freezing and thawing as compared to the air dried samples. Samples containing 1 per cent hydrated lime showed a slight increase in unconfined compressive strength when subjected to the freeze-thaw test as compared to the air dried samples. For both the series of samples containing no hydrated lime and the series containing 1 per cent hydrated lime there was very little difference in the unconfined compressive strengths for the various residual asphalt contents from 2 to 6 per cent. The maximum unconfined compressive strength of samples containing 3 per cent hydrated lime when subjected to the freeze-thaw curing period was 28.0 pounds per square inch at a residual asphalt content of 4 per cent. This was an increase of 8.4 pounds per square inch over a similar set of samples that were air cured before testing.

The samples that were immersed in water for 43 days before testing showed higher unconfined compressive strengths than did similar samples subjected to air dry and freeze-thaw curing periods. The samples containing no hydrated lime and 2 per cent residual asphalt disintegrated completely towards the end of the immersion period. For those samples containing no hydrated lime, the unconfined compressive strengths increased with increasing asphalt contents up to a maximum of 8.4 pounds per square inch at 6 per cent residual

asphalt. The unconfined compressive strengths of the samples containing 1 per cent hydrated lime increased with increasing asphalt content up to a maximum of 17.8 pounds per square inch at 5 per cent residual asphalt. The series of samples containing 3 per cent hydrated lime showed a distinct optimum asphalt content of 4 per cent, with a maximum unconfined compressive strength of 35.1 pounds per square inch. This maximum strength at 4 per cent residual asphalt and 3 per cent hydrated lime was an increase of 15.5 pounds per square inch over similar samples that were dried in the air at room temperature before testing.

Molded Dry Density: The effect of various amounts of hydrated lime and emulsion on the molded dry density of the unconfined compression samples is shown in Figure 12. Since there was very little volume change in the specimens when subjected to either the freeze-thaw or water immersion curing periods, there was little change in the molded dry density of the samples at a given asphalt and lime content for the three curing periods. The general tendency was for the dry density of the mix to increase uniformly from 2 to 5 per cent residual asphalt. There was very little increase in the dry density of the samples when the residual asphalt content was increased from 5 to 6 per cent. Samples containing 1 per cent hydrated lime had a greater density than did those samples containing no hydrated lime. Similarily the series of samples with 3 per cent

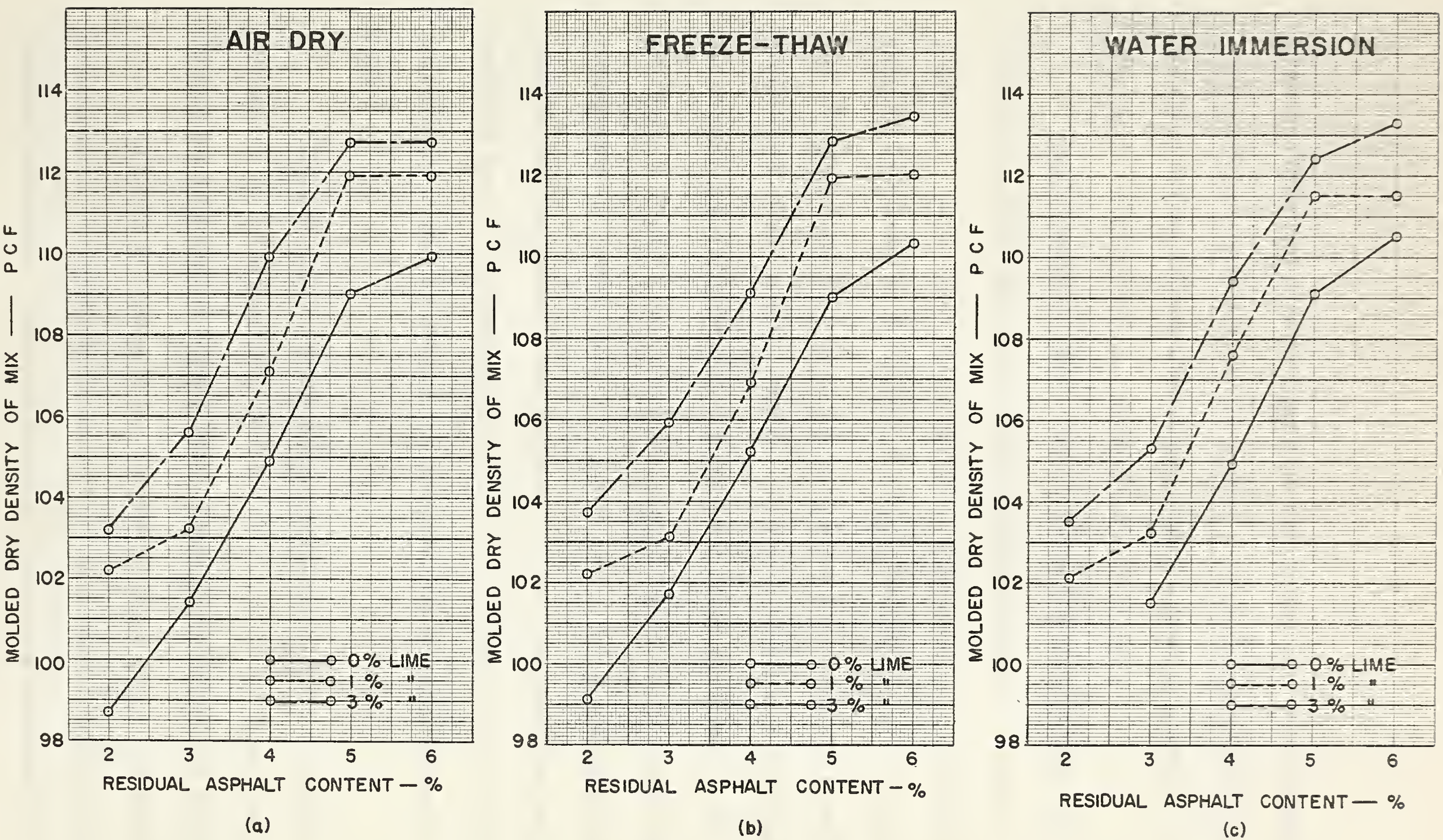

Figure 12: EFFECT OF ASPHALT AND LIME ON THE MOLDED DRY DENSITY OF 2.0" x 5.0" UNCONFINED COMPRESSION SAMPLES SUBJECTED TO AIR DRY, FREEZE-THAW, AND WATER IMMERSION CURING PERIODS.

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hydrated lime had greater densities than either the series containing 1 per cent hydrated lime or the series containing no hydrated lime. All three series followed the same general trend with respect to the increase in density with increasing asphalt content.

Void Content of Mix: The void content of the mix for the various hydrated lime and residual asphalt contents is shown in Figure 13. Since there was very little difference in the volume of the samples subjected to the various curing periods, the void content of the mix changed very little when the samples were tested after the different methods of curing. The percentage of void space in the mix decreased uniformly from 2 to 5 per cent residual asphalt. The decrease in void content was less apparent when the residual asphalt content was increased from 5 to 6 per cent. At a given percentage of asphalt, the void content was highest for those samples containing no hydrated lime. The addition of 3 per cent hydrated lime to the mix decreased the void content of the compacted specimens by about 3 per cent.

Per Cent Voids Filled After Immersion: The percentage of void space in the aggregate filled with water after 43 days total water immersion is shown in Figure 6(a). Samples containing no hydrated lime exhibited a decrease in the amount of water absorbed into the void space in the aggregate with increasing residual asphalt contents. Samples containing 1 per cent hydrated lime had a maximum amount

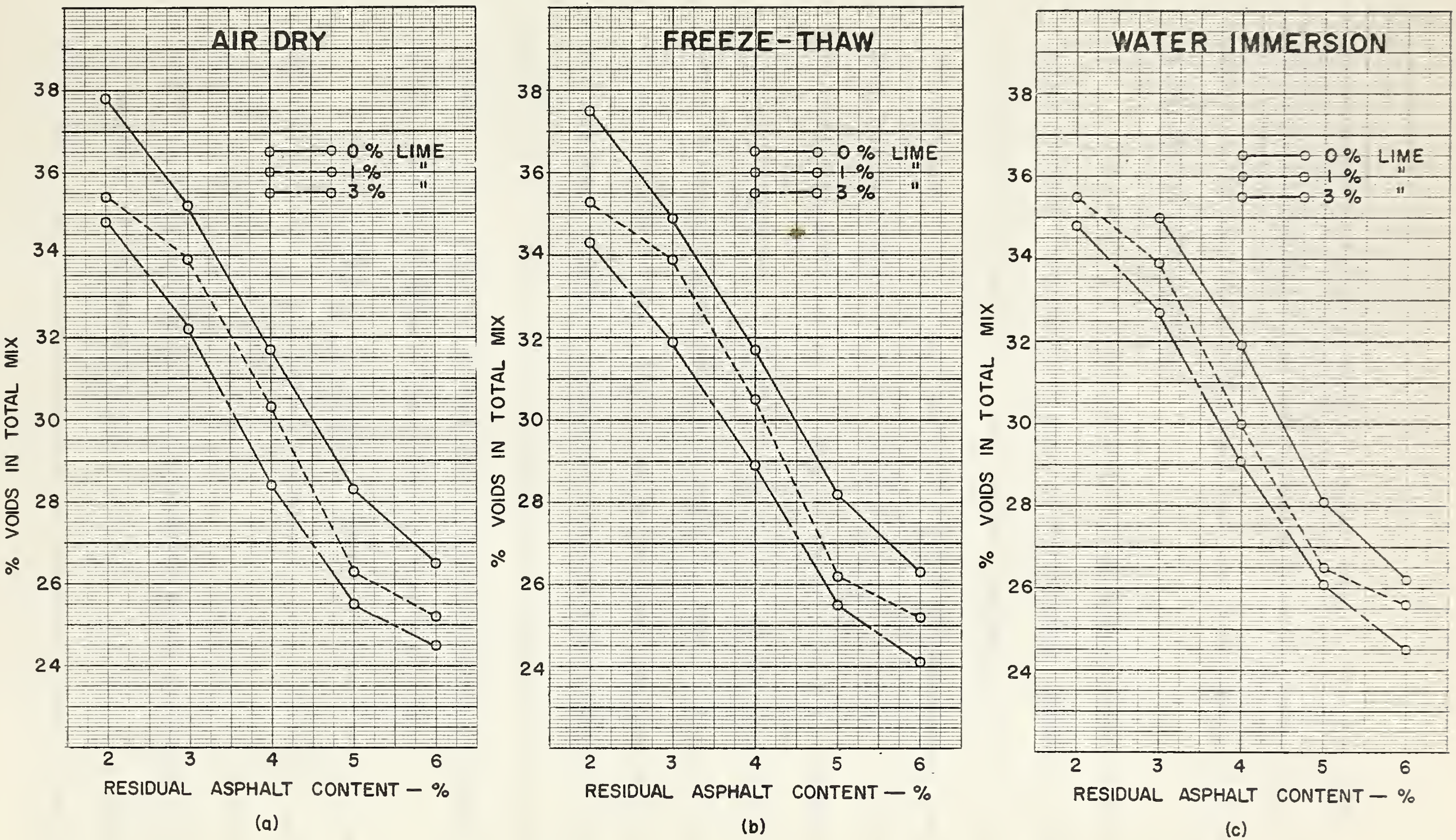

Figure 13: EFFECT OF ASPHALT AND LIME ON THE VOID CONTENT OF THE MIX FOR 2.0"x5.0" UNCONFINED COMPRESSION SAMPLES SUBJECTED TO AIR DRY, FREEZE-THAW, AND WATER IMMERSION CURING PERIODS.

SS-1 EMULSION

of absorbed water at a residual asphalt content of 4 per cent. For samples containing 3 per cent hydrated lime the percentage of void space in the aggregate filled with water varied slightly with the different asphalt contents.

An indication of the amount of void space left in the samples after 43 days immersion is given in Figure 6(c). Samples containing no hydrated lime and 5 per cent residual asphalt had 96 per cent of the void space in the aggregate filled after the immersion period. This was the maximum value obtained for the series of samples containing no hydrated lime. The series of samples containing 1 per cent hydrated lime had a maximum of 83 per cent of the void space in the aggregate filled with asphalt, lime, and water after the immersion period. This occurred at a residual asphalt content of 5 per cent. Samples containing 3 per cent hydrated lime had a maximum of 75 per cent of the voids in the aggregate filled with asphalt, lime, and water after the 43 days total water immersion. In this case the residual asphalt content was 6 per cent.

<u>Rate of Water Absorption:</u> Figure 14 illustrates the rate of water absorption of samples containing 3 per cent hydrated lime and various percentages of residual asphalt. There was no distinct difference in either the rate or the amount of water absorbed by the samples at the various asphalt contents. At the end of the 43 days water immersion all samples had between 42 and 47 per cent

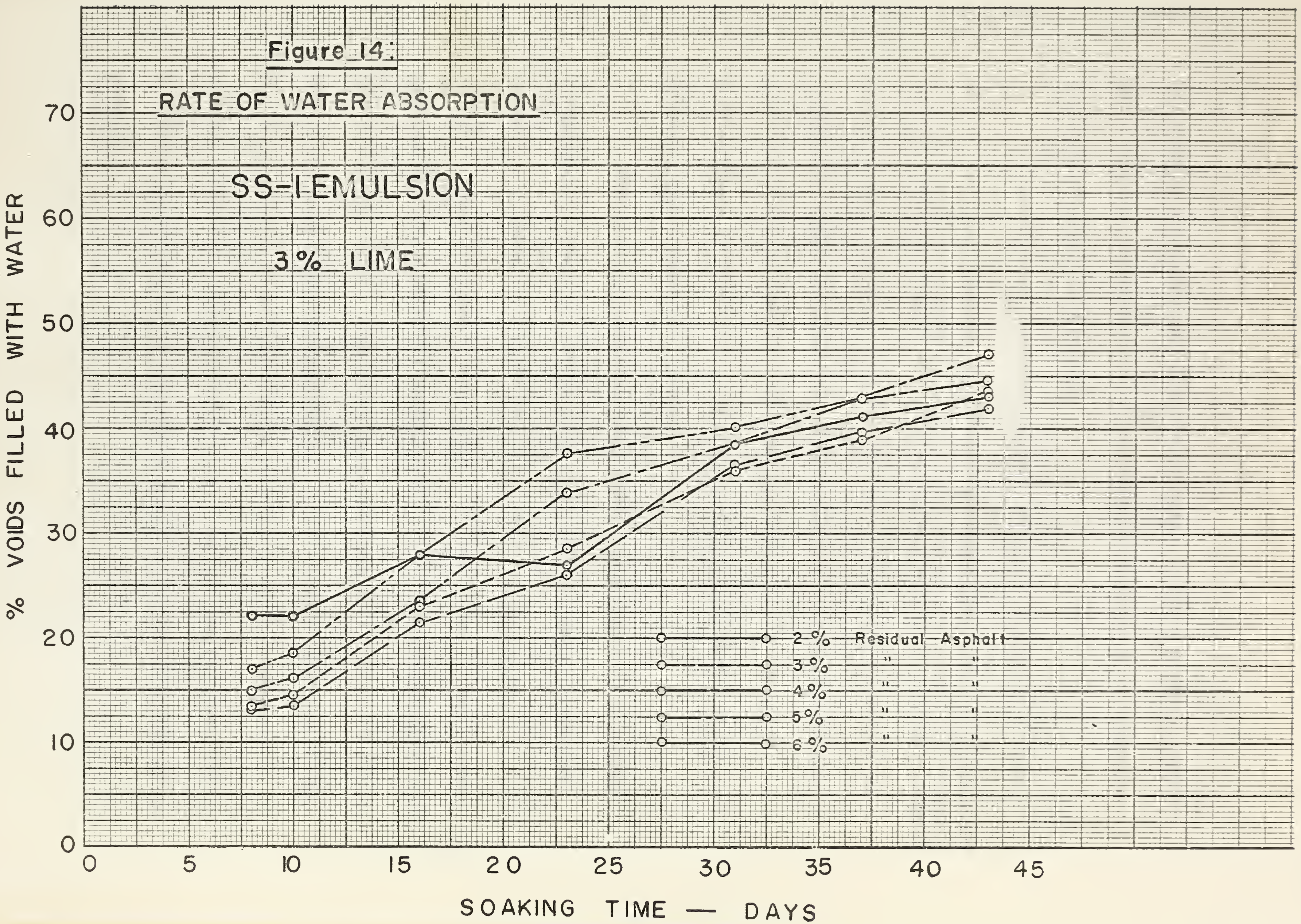
Figure 14:
RATE OF WATER ABSORPTION
SS-1 EMULSION
3% LIME
% VOIDS FILLED WITH WATER
SOAKING TIME — DAYS
0
10
20
30
40
50
60
70
5
15
25
35
45
2 % Residual Asphalt
3 % " "
4 % " "
5 % " "
6 % " "

of voids in the aggregate filled with water. The samples containing 2 per cent residual asphalt suffered a slight loss of material during the immersion period.

The effect of residual asphalt content on the rate and the amount of water absorption of samples containing 1 per cent hydrated lime is shown in Figure 15. The plot for 2 per cent residual asphalt is not realistic because some material was lost from the samples during the immersion period. Excluding the samples containing 2 per cent residual asphalt, all samples had between 50 and 60 per cent of the void space in the aggregate filled with water at the end of the 43 day immersion period.

The rate and the amount of water absorption for samples containing no hydrated lime and varying percentages of residual asphalt are shown in Figure 16. The samples containing 2 per cent residual asphalt began to lose material after about 23 days immersion, and towards the end of the immersion period, these samples disintegrated completely. The samples containing 3, 4, 5, and 6 per cent residual asphalt had between 63 and 76 per cent of the void space in the aggregate filled with water after the complete immersion period. The samples containing 6 per cent residual asphalt showed a definite decrease in the amount of water absorbed over the other samples.

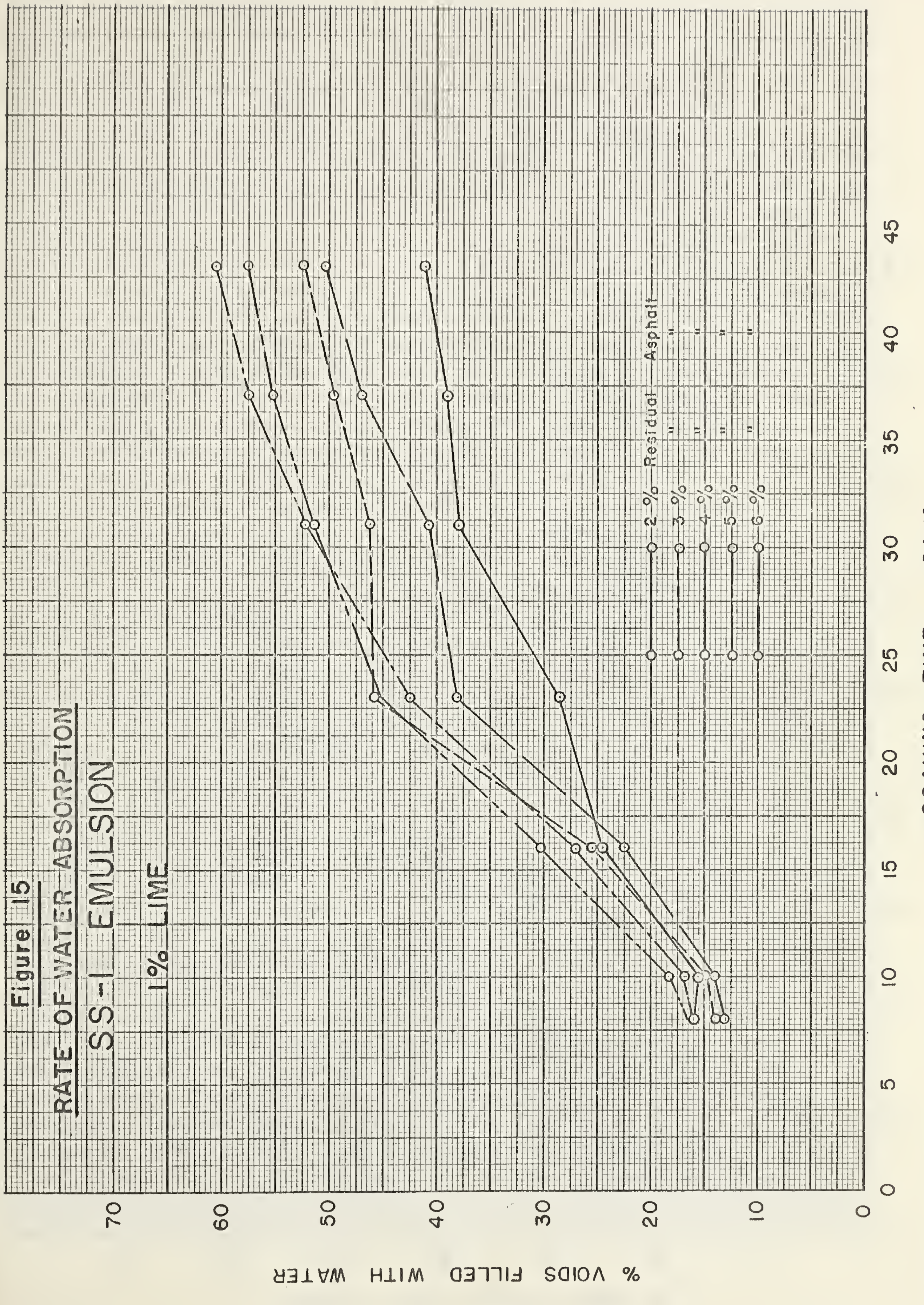

Figure 15
RATE OF WATER ABSORPTION
SS-1 EMULSION
1% LIME

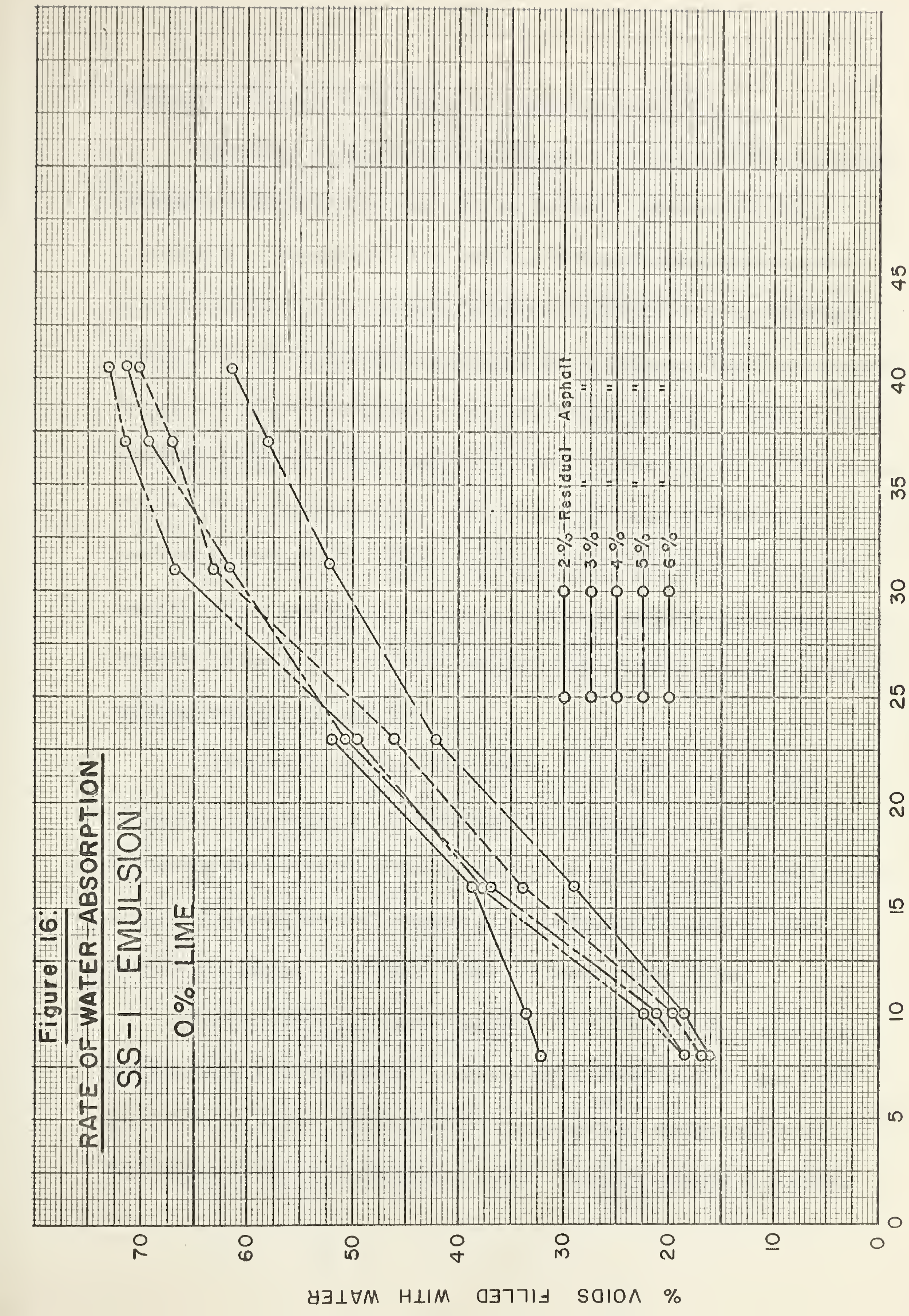

Figure 16:
RATE OF WATER ABSORPTION
SS-1 EMULSION
0% LIME
2% Residual Asphalt
3% " "
4% " "
5% " "
6% " "
SOAKING TIME — DAYS
% VOIDS FILLED WITH WATER
0
5
10
15
20
25
30
35
40
45
10
20
30
40
50
60
70

Modified Hubbard-Field Tests on Sand-Emulsion Samples:

Modified Hubbard-Field Stability: The results of the Modified Hubbard-Field Stability tests run on the sand-emulsion samples are shown in Figure 17. The results of the samples broken after air curing indicate there was very little difference in the Modified Hubbard-Field Stability of samples with no hydrated lime as compared to those samples containing 1 per cent hydrated lime. The maximum Modified Hubbard-Field Stability for both series was about 600 pounds at a residual asphalt content of 4 per cent. Samples containing 3 per cent hydrated lime showed a considerable increase in strength over the other two series, with the maximum Modified Hubbard-Field Stability of the 3 per cent lime series being 1470 pounds at a residual asphalt content of 5 per cent.

As shown in Figure 17(b), water immersion for 43 days reduces the strength of the samples containing no hydrated lime and increases the strength of the samples containing 1 per cent hydrated lime. The samples containing 3 per cent hydrated lime showed very little change in strength after the immersion period.

Molded Hubbard-Field Density: The effect of hydrated lime and asphalt on the dry density of the mix is shown for the air dried specimens in Figure 17(c) and for the specimens subjected to 43 days water immersion in Figure 17(d). The dry density of the mix

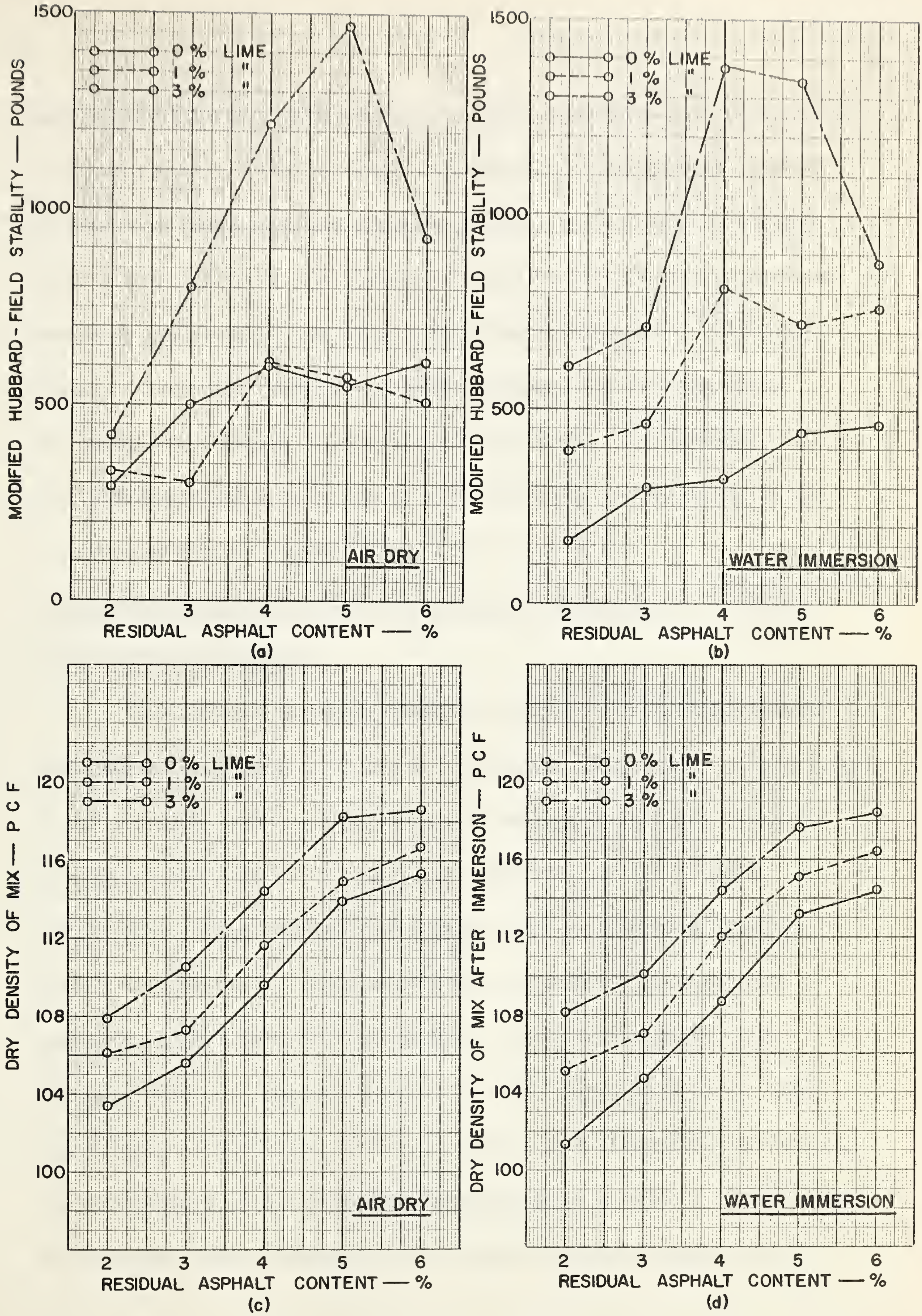

Figure 17: EFFECT OF ASPHALT AND LIME ON DENSITY AND HUBBARD-FIELD STABILITY — SS-1 EMULSION.

increased uniformly with increasing asphalt content up to 5 per cent residual asphalt. The increase in density with increasing asphalt content was less apparent when the asphalt content was increased from 5 to 6 per cent. All series of samples containing the various amounts of hydrated lime exhibited the same tendency. The addition of 1 per cent residual asphalt increased the dry density of the sample by roughly 4 pounds per cubic foot. The addition of 3 per cent hydrated lime to the mix increased the dry density of the samples by about 4 pounds per cubic foot as well.

Relation Between Unconfined Compressive Strength and Modified Hubbard-Field Stability:

The relation between Modified Hubbard-Field Stability and unconfined compressive strength is shown in Figure 18. The results of the strength tests on only the air dried specimens are shown in this figure, with each point plotted being the average of three specimens. Figure 18 indicates there is a considerable scatter among the points, but it appears that a Modified Hubbard-Field Stability of 1000 pounds is equal to an unconfined compressive strength value of between 10 and 15 pounds per square inch. The dry density of the Hubbard-Field samples was about 105 per cent of the dry density of the unconfined compression samples. Work done by Rice and Goetz indicated that a Hubbard-Field Stability value of

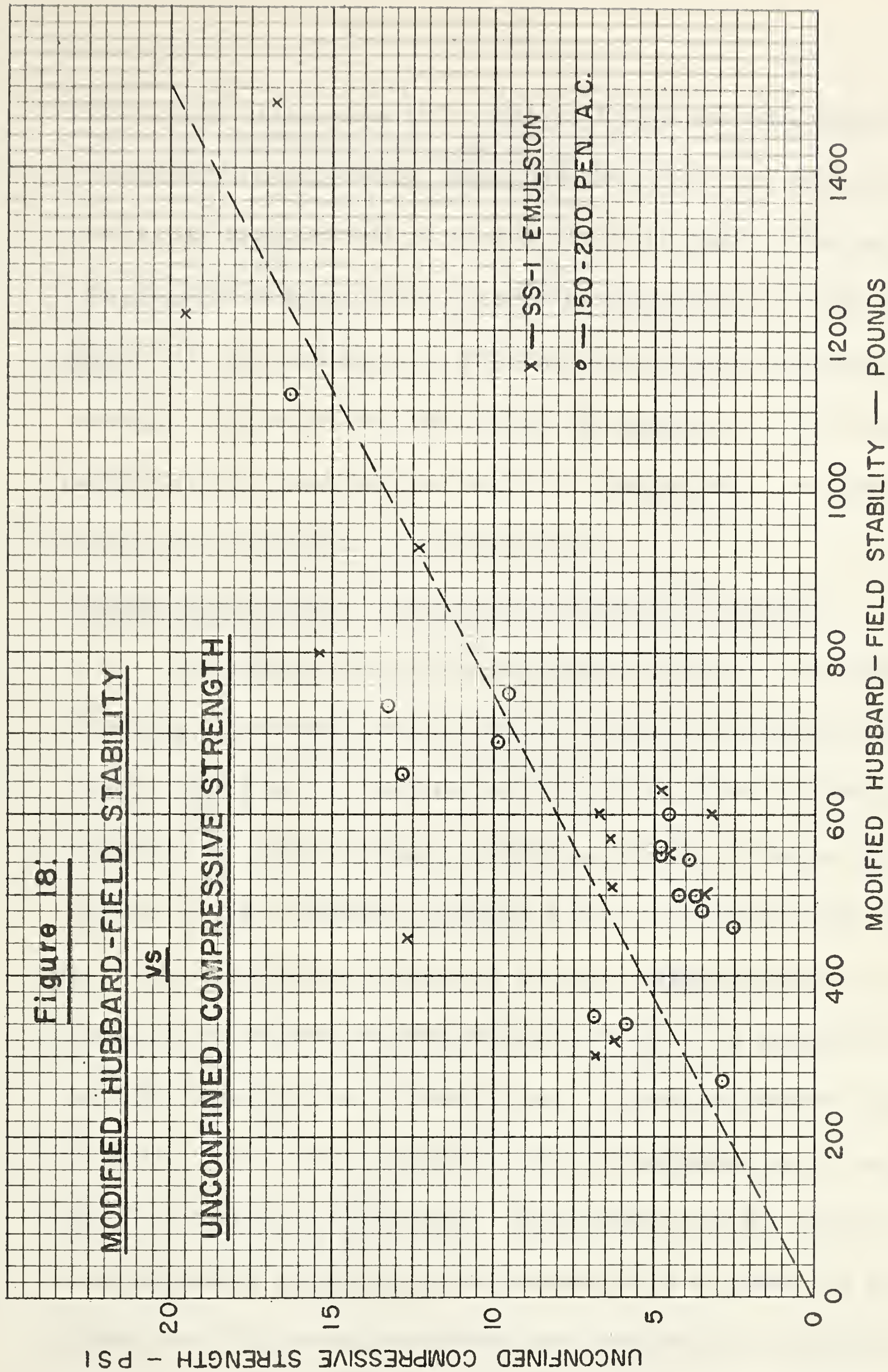
Figure 18.
MODIFIED HUBBARD-FIELD STABILITY
vs
UNCONFINED COMPRESSIVE STRENGTH
x — SS-1 EMULSION
o — 150-200 PEN. A.C.
MODIFIED HUBBARD-FIELD STABILITY — POUNDS
0
200
400
600
800
1000
1200
1400
UNCONFINED COMPRESSIVE STRENGTH - PSI
0
5
10
15
20

1000 pounds when tested at 77 degrees Fahrenheit was equal to an unconfined compressive strength of 60 pounds per square inch at a testing temperature of 100 degrees Fahrenheit. The unconfined compression samples were 2 inches in diameter by 2 inches in height. (24) Since there are differences in the specimen size, the testing temperature, and the molded dry density, no direct comparison can be made between the work done by Rice and Goetz and the results obtained in this investigation.

Triaxial Compression Tests on Sand-Emulsion Mixtures:

The results of the triaxial compression tests run on the 2-inch by 5-inch statically compacted samples are shown in Figure 19 and Figure 20. As illustrated in Figure 19, there is very little difference in either the angle of internal friction or in the unit cohesion of the samples containing 5 per cent residual asphalt from the SS-1 emulsion when tested at the three different rates of strain. The angle of internal friction ranged from 27 to 28 degrees, with the unit cohesion being between 3 and 4 pounds per square inch in all tests. The average dry density of the aggregate in the samples was 98.9 pounds per cubic foot. The triaxial test run on the natural sand yielded an angle of internal friction of 31 degrees and a unit cohesion of 1.5 pounds per square inch with the dry density of the sand in the tests being 92.8 pounds per cubic foot. Had the dry density of the natural sand been increased to about 99 pounds per

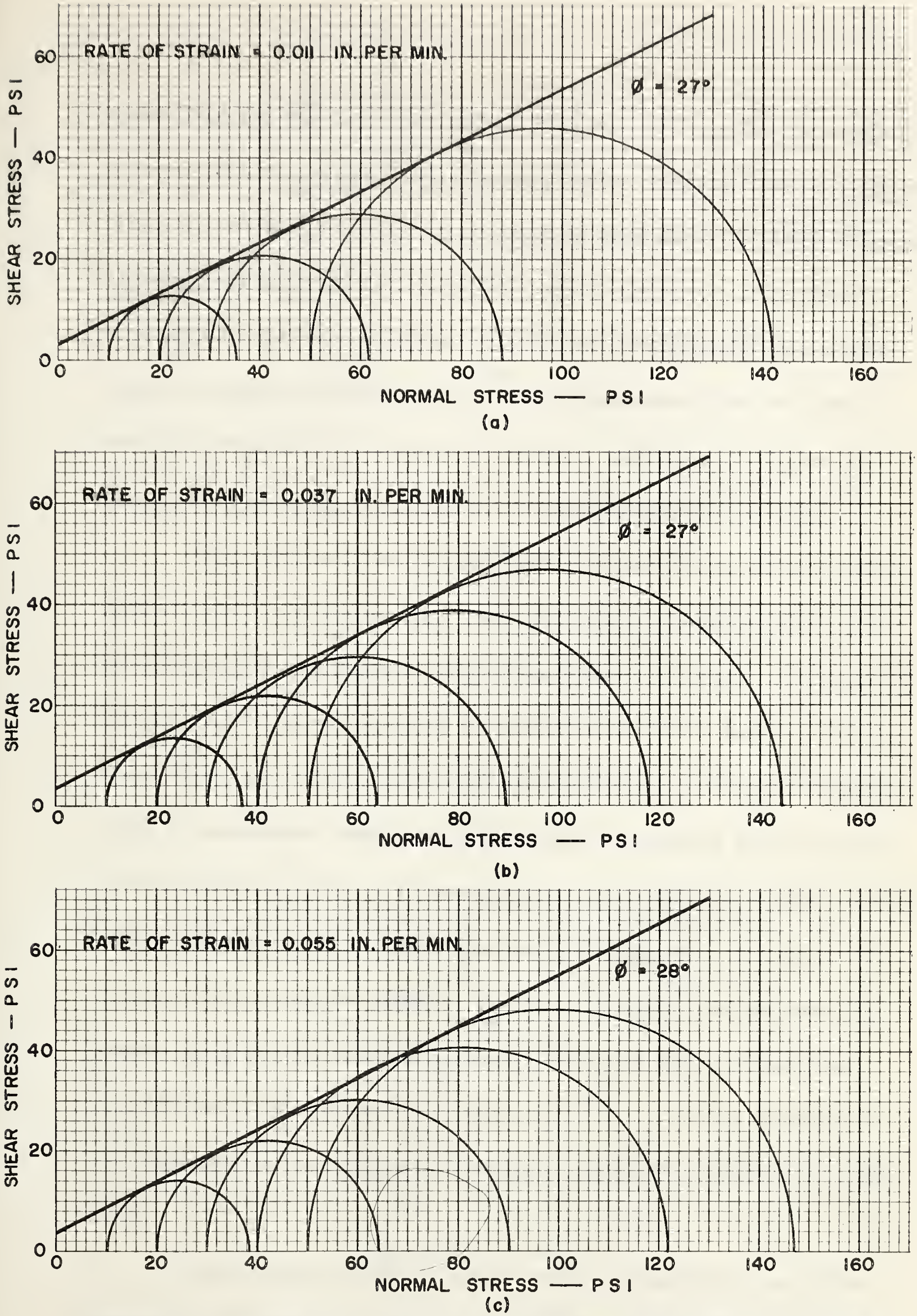

Figure 19: MOHR ENVELOPES FOR 2"x5" SAMPLES CONTAINING 5% RESIDUAL ASPHALT USING SS-1 EMULSION.

cubic foot for the test specimens, it is quite likely that the angle of internal friction would have been somewhat greater than 31 degrees. Thus the addition of 5 per cent residual asphalt to the sand decreased the angle of internal friction by at least 4 degrees. The shear strength as determined by the unconfined compression tests was about 4 pounds per square inch. This compares quite well with the unit cohesion of 4 pounds per square inch obtained from the triaxial compression test run at a comparable rate of strain.

The results of the triaxial compression tests on the sand-asphalt mixtures containing 5 per cent residual asphalt from the SS-1 emulsion and 3 per cent hydrated lime are shown in Figure 20. The angle of internal friction varied from 25 to 26 degrees for the three different rates of strain used, with the unit cohesion ranging from 7 pounds per square inch at a rate of strain of 0.011 inches per minute to a value of 14 pounds per square inch at a rate of strain of 0.055 inches per minute. The unit cohesion was increased from 1.5 pounds per square inch for the natural sand to 14 pounds per square inch for the treated material, with the angle of internal friction being decreased by about 6 degrees. The dry density of the aggregate in the stabilized samples was 100.1 pounds per cubic foot.

Considering all the triaxial compression tests run in this investigation, the shear stress developed in any of the stabilized

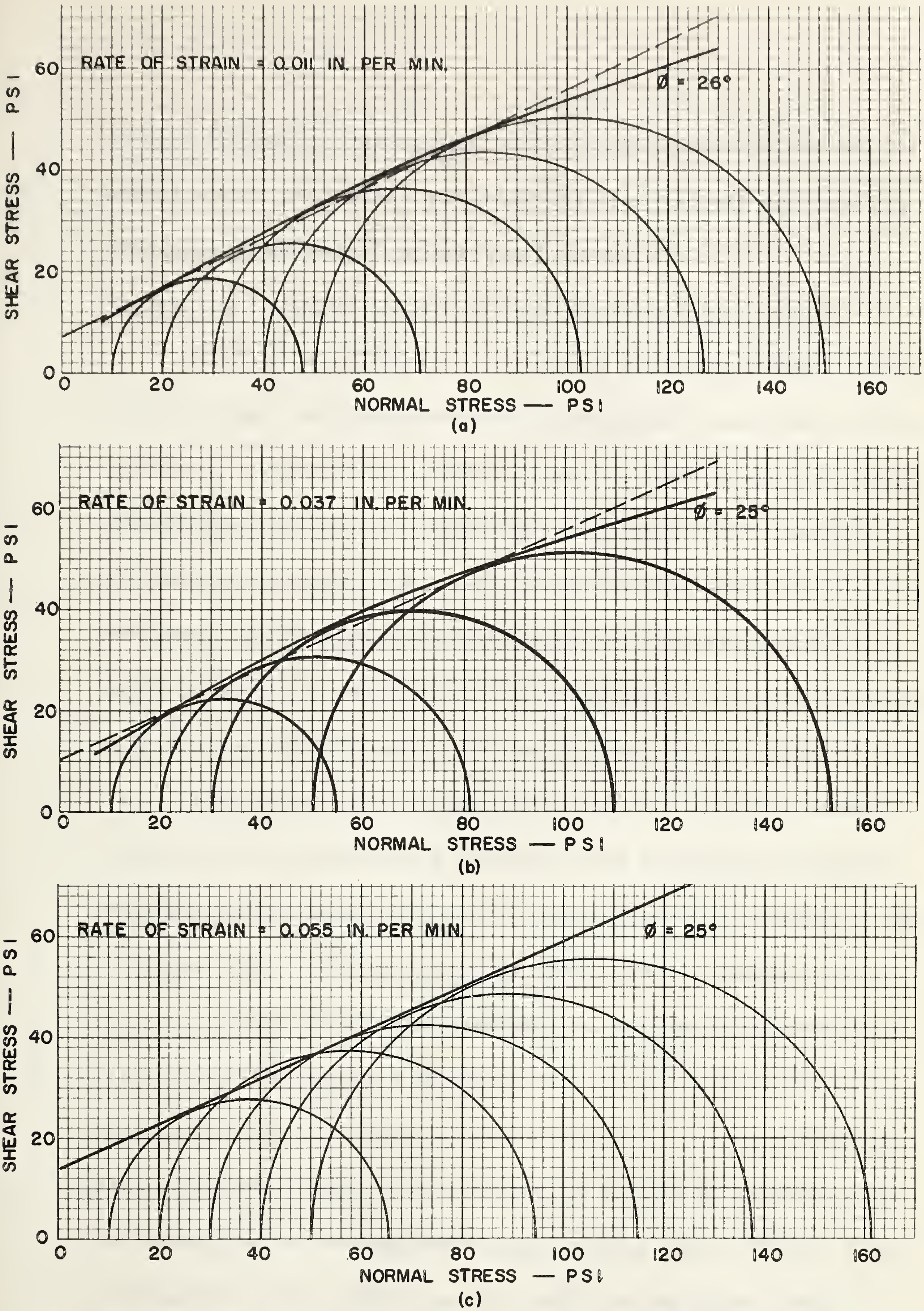

Figure 20. MOHR ENVELOPES FOR 2" x 5" SAMPLES CONTAINING 5% RESIDUAL ASPHALT AND 3% LIME — SS-1 EMULSION.

soils at 100 pounds per square inch normal stress was between 54 and 59 pounds per square inch while the shear stress developed in the natural sand was 62 pounds per square inch.

Variation in Strength and Density with Molding Water Content:

In order to determine the effect of the molding water content on the strength and dry density of the compacted specimens a series of tests were undertaken in which mixes were made up at one water content and dried back to various water contents before molding. All samples contained 5 per cent residual asphalt from the SS-1 emulsion. Those samples with no hydrated lime were mixed at a water content of 14 per cent and those samples containing 3 per cent hydrated lime were mixed at a water content of 17 per cent.

The effect of the molding water content on the dry density of the statically compacted 2-inch by 5-inch samples containing a residual asphalt content of 5 per cent from the SS-1 emulsion is shown in Figure 21(a). It appears that the maximum dry density of 105.4 pounds per cubic foot can be obtained at a molding water content of 7.0 per cent and also at a molding water content of less than 1.0 per cent. Samples molded to the dry side of 7.0 per cent showed decreasing densities, but the dry density seemed to increase when the molding water content was 1.0 per cent or less. From a visual examination of the mixtures as they were drying in the oven, it

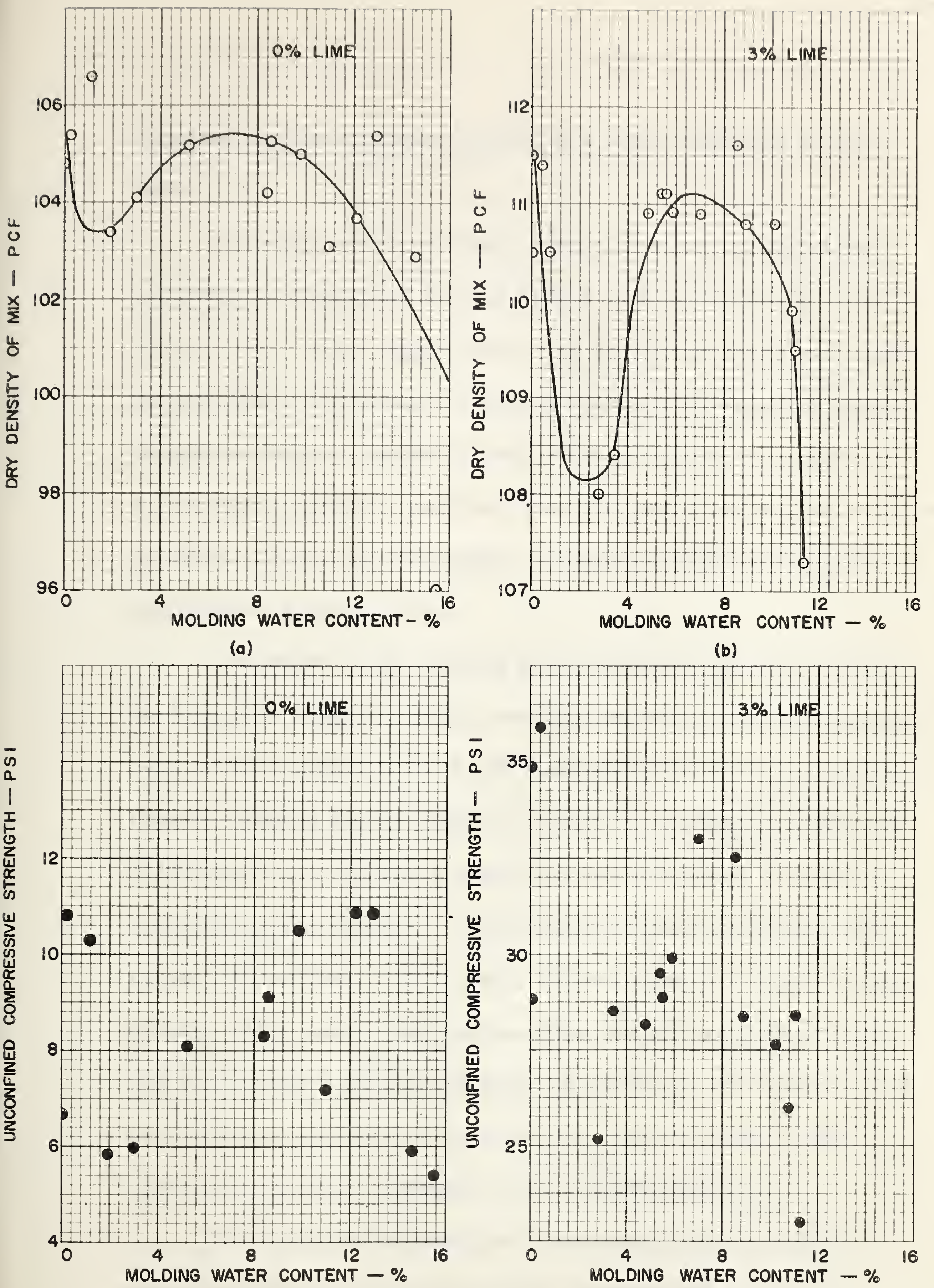

Figure 21 EFFECT OF MOLDING WATER CONTENT ON DRY DENSITY AND UNCONFINED COMPRESSIVE STRENGTH OF STATICALLY COMPACTED SPECIMENS CONTAINING 5% RESIDUAL ASPHALT — SS-1 EMULSION.

appeared that the emulsion "broke" at a water content of 1.0 per cent.

The effect of the molding water content on the unconfined compressive strength of the 2-inch by 5-inch specimens is shown in Figure 21(c). There appeared to be no definite relationship between the unconfined compressive strength and the molding water content though maximum unconfined compressive strengths were observed for samples molded at less than 1 per cent water and also on samples molded at 10 to 13 per cent water. These strengths were similar to those shown in Figure 11(c).

The effect of the molding water content on the dry density of the 2-inch by 5-inch statically compacted specimens containing 5 per cent residual asphalt from the SS-1 emulsion and 3 per cent hydrated lime is shown in Figure 21(b). A maximum dry density of the mix of between 111.0 and 111.5 pounds per cubic foot was obtained at a milding water content of 7.0 per cent and also at a molding water content of less than 1.0 per cent. The variation in dry density with molding water content was the same for this mix as it was for the mix with no hydrated lime although the maximum dry density at 7.0 per cent water occurred over a smaller range of molding water contents for the mix containing 3 per cent hydrated lime.

The variation in unconfined compressive strength of the samples containing 5 per cent residual asphalt and 3 per cent

hydrated lime with the molding water content is illustrated in Figure 21(d). There appeared to be no definite relationship between the molding water content and the unconfined compressive strength although the highest compressive strengths were observed on samples molded at a water content of about 8 per cent and also on samples molded at a water content of between 0 and 1 per cent. The strengths at 0 to 1 per cent molding water content corresponded to those shown in Figure 11(c).

As shown in Figures 22(c) and 22(d), the molding water content appears to have an effect on the amount of water absorbed into the 2-inch by 5-inch statically compacted specimens after 43 days complete water immersion. The samples containing 3 per cent hydrated lime and 5 per cent residual asphalt appeared to pick up more water as the molding water content was increased. On the other hand mixes containing no hydrated lime and 5 per cent residual asphalt from the emulsion appeared to pick up less water as the molding water content was increased from 0 to 12 per cent. Samples molded at water contents greater than 12 per cent appeared to pick up more water than those molded at 12 per cent.

The results of the standard AASHO compaction test on the sand-emulsion mix containing 3 per cent hydrated lime is shown in Figure 22(a). This plot indicates that the maximum dry density of the mix is 113.0 pounds per cubic foot at an optimum moisture

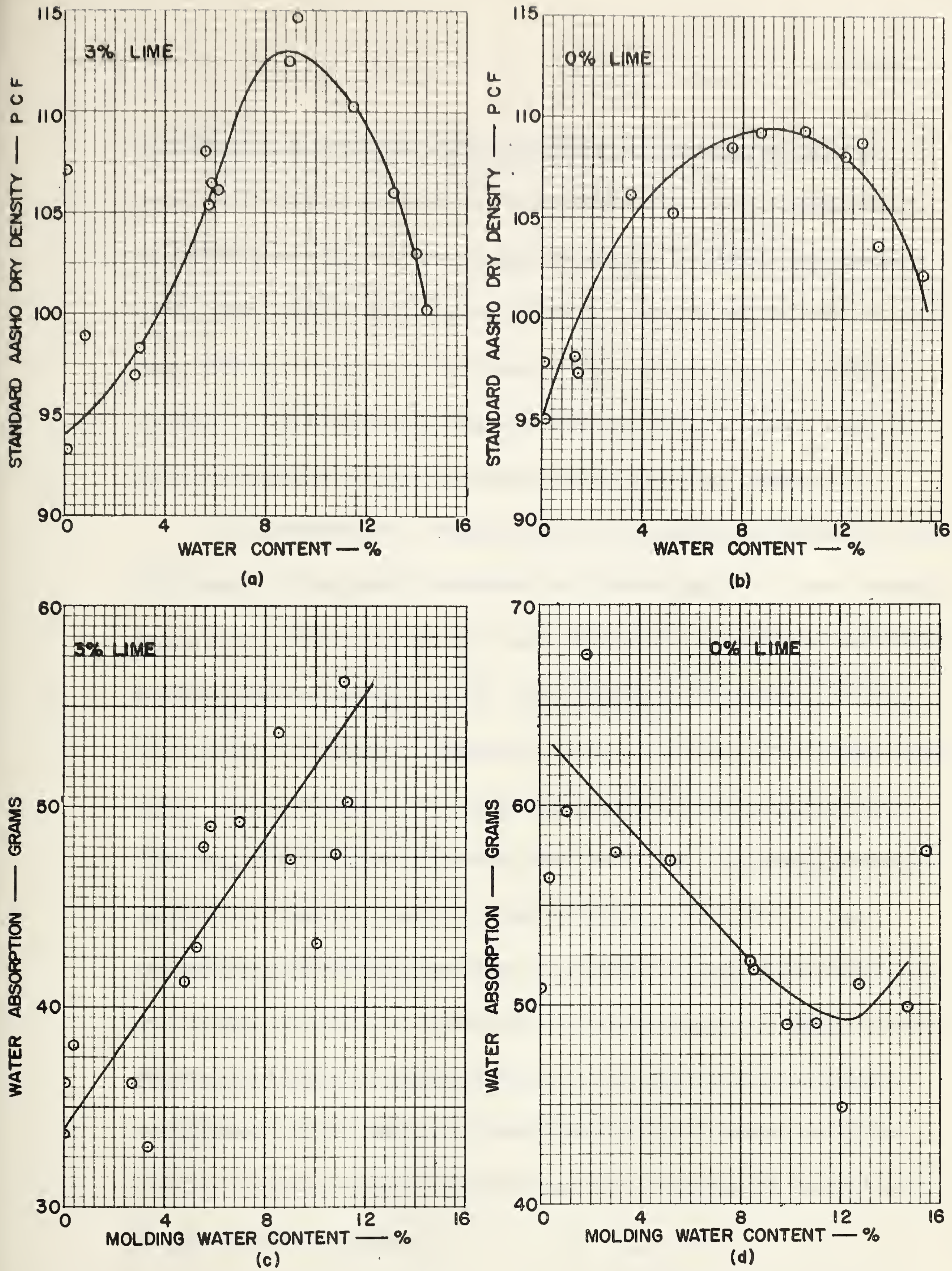

Figure 22: STANDARD AASHO COMPACTION CURVES AND WATER ABSORPTION OF 2" x 5" SAMPLES AFTER 43 DAYS WATER IMMERSION FOR A SAND EMULSION MIX CONTAINING 5% RESIDUAL ASPHALT.

content of 9.0 per cent. The maximum dry density of the mix obtained by static compaction in the 2-inch by 5-inch mold was about 98.5 per cent of the maximum standard AASHO dry density of the mix. Since the optimum moisture content of the natural sand was 14.0 per cent, it would appear that the 5 per cent residual asphalt in the mix was acting in a similar manner to the water in lubricating the soil particles and thus facilitating compaction.

As illustrated in Figure 22(b), the maximum standard AASHO dry density of the sand-emulsion mix containing 5 per cent residual asphalt was 109.5 pounds per cubic foot at an optimum moisture content of about 9.0 per cent. The maximum dry density of the mix obtained by static compaction in the 2-inch by 5-inch molds was about 96.5 per cent of the maximum standard AASHO dry density. The range of moisture contents over which the maximum standard AASHO dry density could be obtained was greater for the mix containing no hydrated lime than it was for the mix containing 3 per cent hydrated lime. In this mix as well, the residual asphalt cement appeared to act in a similar manner to the water in promoting compaction. This was quite possible since at a water content of 9.0 per cent the residual asphalt was still mixed with the water in the form of an emulsion.

Comparison of Hydrated Lime and Silt as Secondary additives:

The data collected from the tests run on the samples containing the hydrated lime and the silt is shown in Appendix "G". All test properties are the average of 5 specimens containing 5 per cent residual asphalt from the SS-1 emulsion. The samples were tested in unconfined compression after being completely immersed in water for a period of 44 days.

The unconfined compressive strength of the samples containing no secondary additive was 5.30 pounds per square inch, as compared to 7.63 pounds per square inch for the samples containing 3 per cent silt and 21.77 pounds per square inch for the samples with 3 per cent hydrated lime. The molded dry density of the mix with no secondary additive was 104.0 pounds per cubic foot as compared to 105.2 pounds per cubic foot for the samples containing 3 per cent silt and 107.2 pounds per cubic foot for the samples with 3 per cent hydrated lime. The samples with no secondary additive picked up 61 grams of water during the immersion period while the samples containing 3 per cent silt picked up 67 grams and the samples with 3 per cent hydrated lime picked up only 49 grams of water. The silt used conformed to the gradation requirements for mineral filler and had a plasticity index of 5. It can be seen from these tests that hydrated lime was more effective in increasing dry density, increasing the strength, and reducing the water absorption than the silt.

Comparison of SS-1 Emulsion and 150-200 Penetration Asphalt:

All comparisons made in this discussion are on the basis of residual asphalt content. The unconfined compressive strengths of the samples containing no hydrated lime were about the same for the mixes made of the 150-200 penetration asphalt cement and the SS-1 emulsion. The effect of the addition of 1 per cent and 3 per cent hydrated lime to the mix on the increase in unconfined compression strength was more pronounced in the sand-emulsion mixes than in the samples containing the 150-200 penetration asphalt cement. The addition of 3 per cent hydrated lime was much more beneficial in increasing the unconfined compressive strength of the samples than the addition of 1 per cent hydrated lime.

The molded dry density of the 2-inch by 5-inch statically compacted samples was slightly greater for those samples made with the mixes containing the SS-1 emulsion. The increased density obtained with the emulsion was especially noticeable in the range of 3 to 5 per cent residual asphalt. The maximum difference in density was 7 pounds per cubic foot for the mix containing 5 per cent residual asphalt cement and 3 per cent hydrated lime.

The void content of the mixes using the two different asphalts was approximately the same. At residual asphalt contents of 4 to 5 per cent, the void content of the sand-emulsion mixes was about 2 to 4 per cent lower than the corresponding mixes containing the

150-200 penetration asphalt cement.

Samples molded with the SS-1 emulsion had a larger percentage of the void space in the aggregate filled with water after the 42 to 43 day immersion period than the samples containing the 150-200 penetration asphalt cement. This difference in the amount of water absorption was more pronounced for the samples containing no hydrated lime. Samples with the 150-200 penetration asphalt cement had a maximum of 70 per cent of the void space in the aggregate filled with asphalt, lime, and water after the immersion period. All sand-emulsion samples containing 4, 5, and 6 per cent residual asphalt had between 70 and 96 per cent of the void space in the aggregate filled with asphalt, lime, and water after a similar immersion period. Thus, even though the densities of the sand-emulsion samples were generally larger than those of the sand-penetration asphalt samples, the sand-emulsion samples absorbed more water.

Suggested Mix Design and the Resultant Properties:

The results of the Modified Hubbard-Field Stability tests run on the sand-asphalt samples indicated that samples made using the emulsion and the penetration grade of asphalt cement had comparable strengths as far as the mixes containing 0 and 1 per cent hydrated lime were concerned. The sand-emulsion mix containing

3 per cent hydrated lime showed a somewhat higher strength than the mix containing the 150-200 penetration asphalt cement. The results of an analysis of the void content of the sand-asphalt mixes indicated there was no upper limit to the asphalt content as far as this property was concerned. The Modified Hubbard-Field Stability tests indicated that only the mixes having 3 per cent hydrated lime yielded stability values in excess of 1000 pounds within the range of 4 to 6 per cent residual asphalt.

It would appear that if this material was to be stabilized with asphalt, the 3 per cent hydrated lime would have to be added to the mix in order to bring the strength up to an acceptable value. In order for the cementing action of the hydrated lime to take place there must be a certain amount of water in the soil. As a result of this factor, the emulsified asphalt is more readily adaptable to this particular type of stabilization than is the penetration grade of asphalt cement.

Modified Hubbard-Field Stability tests on the sand-emulsion mix containing 3 per cent hydrated lime indicated the optimum asphalt content to be somewhere between 4 and 5 per cent residual asphalt. The results of the unconfined compression tests on the same material indicated the maximum unconfined compressive strength occurred at a residual asphalt content of 4 per cent. Since the

laboratory mixing was probably more efficient than field mixing, a design residual asphalt content of 5 per cent was selected for this material. The emulsion used in this investigation contained 65 per cent residual asphalt cement with the result that 7.7 per cent emulsion would have to be added to the sand in order to obtain the residual asphalt content of 5 per cent. The properties of the sand-emulsion mix containing 5 per cent residual asphalt and 3 per cent hydrated lime are shown in Table XV.

TABLE XVI

SUMMARY OF DESIGN MIX PROPERTIES

Amount of SS-1 emulsion added	7.7 per cent
Residual asphalt content	5.0 per cent
Hydrated lime content	3.0 per cent
Modified Hubbard-Field Stability (air dried)	1470 pounds
Modified Hubbard-Field Stability (water immersion)	1340 pounds
Hubbard-Field dry density	118.0 pcf
Standard AASHO dry density	113.0 pcf
Optimum moisture (Std. AASHO)	9.0 per cent
Unconfined compressive strength after water immersion	33.0 psi
Dry density of 2-inch by 5-inch samples molded under 5000 pound static load	112.7 pcf
Void content of the mix in 2-inch by 5-inch samples	25.5 per cent
Per cent voids in the aggregate filled with asphalt, lime, and water after 43 days water immersion (2-inch by 5-inch samples)	72.5 per cent
Angle of internal friction	25-26 degrees
Unit cohesion	7-14 psi

CHAPTER VII

GENERAL ASPECTS OF TESTING STABILIZED SOILS

There have been many investigations conducted in the field of soil-asphalt stabilization, and much valuable information has been gained from this work. Because of the lack of standardized test procedures, there is always difficulty in relating the findings of these different research programmes. The following comments seem justified in the light of information gained from the testing programme, the literature review, and the experience gained from the construction of sand-asphalt mixes in Manitoba.

Strength Testing:

The Modified Hubbard-Field Stability test was used in this investigation because the Highways Branch of the Province of Manitoba has gained considerable experience in the use of this test for the design and field control of sand-asphalt mixes. From the construction experience it has been found that a mix with a Modified Hubbard-Field Stability of 1000 to 1200 pounds was satisfactory for use as a stabilized base course material when covered with a suitable wearing surface. The particular type of wearing surface used is dependant to a large extent on the traffic conditions. In Manitoba seal coats have been used as the

wearing surface over sand-asphalt mixes on highways where traffic volumes were under 1000 vehicles per day, and three inches of hot plant mix bituminous surfacing over similar base courses on highways with higher traffic volumes.

The Hubbard-Field Stability test is actually an extrusion test measuring some combination of internal friction and cohesion. These two basic strength variables cannot be separated by an analysis of the data from this test. It is the opinion of the author that this test does not provide a duplication of the stresses that occur in a highway base course under the influence of a wheel load. Another disadvantage to this test lies in the fact that it cannot be performed on non-plastic soils which have no stabilizing agent. The results obtained in testing cohesive soils are also somewhat dubious, again due to the fact that cohesion and friction cannot be separated.

As an attempt to approach the problem of determining the strength of a stabilized soil mass from a more fundamental point of view, it was decided to run unconfined compression tests in conjunction with the Modified Hubbard-Field Stability tests. The unconfined compression test was selected because it also is relatively easy to perform, and it would give a direct measure of the cohesion in the stabilized soil. The results of tests on the stabilized soil could be compared to the results of unconfined compression tests run on natural cohesive soils. In addition the

size of the unconfined compression samples was 4 to 5 times that of the Hubbard-Field samples, with the result that less accurate measurements of weight and volume were necessary for the same relative accuracy of the mix properties. A length to diameter ratio of 2.5 was used in order to reduce the effect of end friction on the strength of the sample. The constant volume sample was used in order to simplify the calculations of the mix properties. A rate of strain of 0.045 inches per minute was used for all the unconfined compression tests. For a 5 inch high sample, this is equivalent to a rate of strain of 0.9 per cent per minute, which is within the range of 0.5 per cent to 2.0 per cent per minute commonly recommended for unconfined compression testing. (27)

The unconfined compression test, though it does give a measure of the cohesion existing in the soil sample, does not yield a true picture of the stresses developed when the stabilized base course material is under the influence of a wheel load because the soil in the pavement structure is given some degree of lateral support when the wheel load is applied. As a result of this confining action in the pavement structure, the results of unconfined compression tests may be misleading. For example, the untreated sand used in this investigation had no cohesion while the same sand stabilized with 5 per cent asphalt and 3 per cent hydrated lime had

an unconfined compressive strength of 25 to 30 pounds per square inch. The results of triaxial compression tests on similar samples indicated that, at a normal stress of 100 pounds per square inch, the shear stress developed in the natural sand was higher than that developed in the stabilized material.

On the basis of this information, it appears that the triaxial compression test more closely duplicates the conditions occurring in the pavement structure under the application of a wheel load than either the unconfined compression test or the Hubbard-Field Stability test. One of the major problems in using the triaxial compression test is ascertaining the degree of confinement that exists in the stabilized base course.

As far as basic research work is concerned, the triaxial compression test appears to be the most useful means of evaluating stabilized materials. For routine mix design and field control, tests such as the Hubbard-Field Stability test or the unconfined compression test appear to be more suitable than the triaxial compression test because of the time element involved in laboratory testing. The Province of Manitoba has found the Modified Hubbard-Field Stability test to be extremely useful in this regard.

Curing of Specimens:

Once the method of strength evaluation has been selected, it is then necessary to decide how the samples will be cured prior to testing. The curing conditions should approximate the conditions existing in the field. Probably the three most important curing conditions are water immersion, freezing and thawing, and wetting and drying.

The freeze-thaw test used in this investigation was an open type of freeze-thaw test wherein the sample was given access to water at the bottom while freezing took place from the top. This type of test gives an indication of the degree of capillary rise that may exist in the stabilized soil, and the effect of freezing this capillary water on the strength of the specimens. The other type of freeze-thaw test that may be used could be termed a closed test. In this test the sample has some water in the voids at the start of the test. The moist sample is then subjected to cycles of freezing and thawing and the effect of this type of curing on the strength of the sample may be determined.

The results of the total water immersion tests conducted in this investigation indicated that after about 42 to 44 days immersion the samples containing 5 per cent residual asphalt had about 95 per cent of the void space in the aggregate filled with asphalt, lime, and water. It is rather unlikely that this degree of saturation would

ever be obtained in the field. Based on this fact, it would appear that testing of a completely saturated sample is unnecessary. The actual degree of saturation required at the time of testing could be determined by making field observations on existing soil-asphalt mixtures to determine the degree of saturation that exists in the in-place soil-asphalt mix.

The effects of the various curing periods should be evaluated by considering the loss in strength of the sample as compared to control specimens. Strength, however, should not be the only criterion to determine the suitability of the stabilized material. Factors such as water absorption and swelling should also be taken into account.

Suitable Strength Values:

Considerable experience with the Hubbard-Field Stability test has been gained from the construction projects in Manitoba. In general, it has been found that a sand-asphalt mix with a Modified Hubbard-Field Stability value between 1000 and 1200 pounds is suitable for use as a base course material in a highway pavement structure. The initial test project in Manitoba is showing some signs of rutting and edge ravelling after 12 years of satisfactory service. Based on the test results obtained in this investigation and the testing procedures used, it appears that a

satisfactory value for the unconfined compressive strength of the stabilized material would be between 10 and 15 pounds per square inch. No design values can be assigned to the results of the triaxial compression tests since little is known about the degree of confinement of the material in the base course. This is one of the fields in soil stabilization in need of considerable research.

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

Conclusions:

This thesis has been divided into three main parts. The first section of this report has consisted of a review of some of the more pertinent work that has been reported in the field of soil-asphalt stabilization in recent years. The second section has been a review of all sand-asphalt stabilization projects undertaken by the Highways Branch of the Province of Manitoba. An analysis of the material presented in these first two sections indicated there was a problem in stabilizing a poorly graded sand with asphalt. The literature review gave some indication that the addition of hydrated lime to the sand-asphalt mix would increase the strength of the stabilized soil mass. The third part of this thesis involved a laboratory investigation to determine the feasibility of using hydrated lime to increase the strength of the sand-asphalt mix. The following conclusions can be drawn from this investigation.

Suggested Mix Design: It would appear that a sand-asphalt mix containing 4 to 5 per cent residual asphalt from an SS-1 emulsion and 3 per cent hydrated lime would be satisfactory for use as a sand-asphalt base course material. The Modified

Hubbard-Field Stability of such a mix would be in excess of 1300 pounds according to the results obtained in this investigation. Past experience seems to indicate that such a strength value is acceptable.

Suitability of the Various Tests: Tests such as the Modified Hubbard-Field Stability test and the unconfined compression test seem to be satisfactory for use in mix design and field control of sand-asphalt mixes. It is believed that the triaxial compression test gives a better duplication of the stress conditions existing in the pavement structure under the application of a wheel load. For this reason the triaxial compression test is probably the best test to use when conducting a basic research programme dealing with soil stabilization. The curing conditions used in any laboratory investigation should approximate those expected in the field. It appears that it is not necessary to test a sand-asphalt sample that is completely saturated since this condition will hardly ever occur in normal highway pavement structures. Strength should not be the only criterion used in mix design. Factors such as density, water absorption, and swelling or expansion should also be taken into account.

Variation in Strength with Asphalt Content: The results of the Modified Hubbard-Field Stability tests and the unconfined compression tests on the sand containing the 150-200 penetration asphalt cement indicated that the maximum strength was obtained

at an asphalt content of 3 per cent. The variation in strength with asphalt content was generally quite small. The results of a similar series of tests on sand-emulsion samples indicated there was little variation in strength with residual asphalt content within the range of 2 to 6 per cent. The one exception was the mix containing 3 per cent hydrated lime where there was an optimum residual asphalt content of 4 per cent.

Effect of Type of Asphalt: Strengths obtained by using the SS-1 emulsion were approximately the same as the strengths resulting from the addition of the 150-200 penetration grade of asphalt cement to the natural sand. The beneficial effects of the hydrated lime were more pronounced in the sand-emulsion mixtures than in the mixtures containing the 150-200 penetration asphalt cement. The amount of water absorbed by the samples containing the 150-200 penetration asphalt cement was less than that absorbed by the samples of sand-emulsion mix, even though the density of the sand-emulsion samples was higher.

Effect of Hydrated Lime: The addition of 1 per cent hydrated lime to the sand-asphalt mix had little effect on the strength of the samples with the exception of those specimens subjected to the water immersion period. The addition of 3 per cent hydrated lime to the sand-asphalt mix increased the strength of the samples

considerably. This increase in strength was found to occur at all residual asphalt contents, though the magnitude of the increase was greatest at residual asphalt contents between 3 and 5 per cent. The addition of the hydrated lime increased the dry density of the compacted sand-asphalt mixes. This in turn resulted in a decrease in the void content of the mix with the addition of the hydrated lime. The addition of hydrated lime decreased the rate of water absorption by the compacted mixture.

Effect of Silt: The addition of 3 per cent silt to the sand-emulsion mix containing 5 per cent residual asphalt from the SS-1 emulsion resulted in an increase in the amount of water absorbed by the specimens whereas the addition of 3 per cent hydrated lime to a similar series of samples resulted in a decrease in the amount of water absorbed by the specimens as compared to those mixes containing no secondary additive. The addition of 3 per cent hydrated lime to the sand-emulsion mix was more beneficial in increasing the unconfined compressive strength and increasing the dry density of the mix than the addition of 3 per cent silt.

Triaxial Compression Testing: The addition of asphalt to the sand decreased the angle of internal friction and slightly increased the unit cohesion. The addition of 3 per cent hydrated lime to the sand-emulsion mix further decreased the angle of

internal friction and increased the unit cohesion. There was very little difference in the angle of internal friction when the rate of strain was increased from 0.011 to 0.055 inches per minute.

Compaction of Sand-Emulsion Mixtures: Compaction of the sand-emulsion mixtures was most efficient at a water content of 9.0 per cent as indicated by the standard AASHO density determination performed on the material. The adhesional characteristics of the residual asphalt cement were not developed until the emulsion had broken. As a result most of the water would have to be removed from the sand-emulsion mix before a road constructed of this material received too much traffic. With this fact in mind it would seem that the best construction procedure to follow would be to aerate the mixed material until the emulsion had broken before proceeding with compaction. This would be especially true in the late fall. Compaction at this low water content would be more difficult than at the optimum water content of 9.0 per cent, but the resultant compacted material would have more strength.

Recommendations:

There are so many variables in an investigation of this kind that it is virtually impossible to ascertain the effects of all the factors concerned. Probably the most important factor in any

laboratory investigation of a proposed construction project is to have test procedures that approximate the field conditions. Even with the limited scope of this testing programme, over 600 sand-asphalt samples were compacted, cured, and broken. Experience gained from the field construction of sand-asphalt base courses and the information obtained by conducting this laboratory investigation have led to the following recommendations.

Compaction of Samples: The variation in the dry density of the statically compacted 2-inch by 5-inch specimens within the length of the sample should be determined. Many other investigators have used static compaction, but seldom have they used a sample with a length to diameter ratio as large as 2. 5. (24) If the variation in density within the length of the sample is too large, then it is possible that this length to diameter ratio should be reduced.

Curing Time for Sand-Emulsion Mixes: When dealing with an emulsified asphalt, field compaction is most efficient at one particular water content. The water content at which the emulsion will break is generally much lower than this. If the sand-emulsion mix is compacted in the field at the optimum moisture content, it is important to know the time required for the compacted mix to lose enough water in order that the emulsion will break. If this time is greater than one or two weeks, then the mix would have to be aerated until the emulsion broke before attempting compaction.

Feasibility of Portland Cement: Any study involving the improvement of local materials for use in the subbase or base of the pavement structure should include all possible stabilizing agents. Considerable work has been done in recent years with Portland cement and it appears that this material could also be used as a stabilizing agent. Portland cement has been used in the past both as a secondary additive with asphalt, and as a stabilizing agent in itself. It is quite possible that the soil used in this study could be stabilized as effectively with 6 to 8 per cent Portland cement as with the SS-1 emulsion and 3 per cent hydrated lime.

Economic Analysis: If it is found possible to stabilize this material with Portland cement, then these two alternatives should be compared economically.

Test Project: The most reliable method of evaluating the suitability of using hydrated lime in the sand-asphalt mix is to construct a test project. Included in this project should be a short section with no hydrated lime. The treated base should be covered with an asphaltic concrete wearing surface. This test section should be observed continually in order to detect any signs of rutting or shoving on either section. Seasonal and yearly variations in the load carrying capacity of the pavement structure should be evaluated by means of the Benkleman beam.

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APPENDIX "A"

SPECIFICATIONS FOR THE CONSTRUCTION OF A SOIL-ASPHALT STABILIZED BASE COURSE

SPECIFICATIONS FOR THE CONSTRUCTION OF A SOIL-ASPHALT STABILIZED BASE COURSE

1. General Clauses

The General Specifications attached hereto shall apply to and be a part of these Specifications

2. Description

This work shall consist of the construction of a soil-asphalt stabilized base cource and incidental work required in accordance with the terms of these Specifications.

3. Materials

(1) This type of base course will be constructed from an approved subgrade soil of sand texture, with or without the addition of an approved soil admixture.

(2) Bituminous Materials: Bituminous materials will be supplied to the Contractor f.o.b. such sidings as designated by him. The materials shall be as set forth in the Special Provisions.

(3) New Material: The Contractor may be required to supply and haul suitable new material to be placed over the existing subgrade. The depth required to be processed shall be as shown on the plans and cross sections. New material shall be approved by the Engineer and shall be granular with a maximum of twenty (20) per cent passing the No. 200 sieve.

(4) Source of Supply: The Contractor shall notify the Engineer as to the source of supply of new material to be used in the work covered by these Specifications, and shall supply samples to the Highways Branch Testing Laboratory, for approval of its quality and nature, at least ten (10) days prior to its use in the work, Each sample shall contain not less than fifty (50) pounds, and the Contractor shall assume all costs incurred in obtaining and shipping the samples. Preliminary approval of the quality and nature of the material submitted in the samples will not constitute general acceptance of all the material in the deposit or source of supply. Any material of a quality or nature not suitable for its intended purpose will be rejected. No payment will be made for rejected material.

3. Materials: (continued)

(5) Soil Admixture: Whenever required, the Engineer may direct the addition of an approved soil admixture, and such addition shall be deemed and paid for as extra work.

4. Laboratory:

The Contractor shall furnish for the exclusive use of the Engineer one weather proof building to be used as a laboratory. It shall be located as directed by the Engineer and shall be independent of any building used by the Contractor. It shall have a minimum floor area of ninety square feet and a minimum ceiling height of seven feet and shall have three windows and one door with lock. It shall be furnished with one work bench, two feet six inches wide running the full length of the building at a height of three feet six inches above the floor. The building shall be wired for electricity and the Contractor shall supply electricity and water where these are required for testing purposes.

5. Equipment:

Any machine, combination of machines or equipment which will pulverize the soil, apply the asphalt, mix the component materials, perform the operations necessary for aeration of the mixed material where required, and compact and finish the mixture in conformance with these specifications may be used upon approval of the Engineer. This shall include Road Mix, Travel Plants, or Central Plant methods of operation.

6. Construction Methods:

(1) Preparation of the Existing Subgrade: (a) Before stabilized base construction commences the existing subgrade shall be graded, shaped, and compacted to conform with the plans and cross sections.

(b) When directed by the Engineer, where the existing subgrade material is not suitable for bituminous stabilization the Contractor shall haul approved new material to such portions of the road and in such quantities as may be required. All new material placed on the subgrade must be compacted.

(c) The Contractor in borrowing new material either from the right-of-way or borrow pits shall be responsible for the stripping of any material not, in the opinion of the Engineer, suitable for addition to the grade as new material. He shall be responsible for trimming these borrow areas to the satisfaction of the Engineer. This stripping and trimming will not be paid for directly but will be

considered as incidental to "Supplying, Hauling and Compacting New Material."

(d) The moisture content of the soil prior to the application of the bituminous material shall be adjusted by drying or by the addition of water, in accordance with the requirements of the Engineer.

(2) Application of Bituminous Materials: (a) The application of bituminous material shall be as directed by the Engineer and shall not be applied when the air temperature is less than 50 degrees Fahrenheit, or when, in the opinion of the Engineer, weather or roadbed conditions are otherwise unsuitable.

(b) When Road Mix methods are used the bituminous material shall be applied uniformly by means of a pressure distributor of approved type, in successive applications, to the material taken from a windrow which has previously been proportioned by means of an equalizer or other approved means, and in such amounts as directed by the Engineer. The temperature of application of the bituminous material shall be within the range indicated in the Special Provisions for the type and grade of asphalt used. Immediately behind the distributor after each application of asphalt, mixing shall be carried out using pulvi-mixers and blade graders or by other methods satisfactory to the Engineer. The intervals between applications shall be as directed or permitted by the Engineer. The mix shall be manipulated until uniformity has been obtained. During mixing operations care must be taken to avoid cutting into the underlying course or contaminating the mixture with raw soil. All thoroughly mixed material shall be windrowed and kept clear of the raw material. When the depth of soil-asphalt stabilized material is greater than four (4) inches compacted, the mixing operations shall be divided into two or more courses: This does not apply to single pass type travel plants but shall apply to travel plants equipped to operate from windrows.

(c) With special reference to travel plants, if the single pass type of travel plant is utilized for mixing, the progress of the mixing operations, depth of cut, rate and temperature of application of the bituminous material shall be as directed by the Engineer. When travel plants, which are equipped to operate from windrows are used, the windrows shall be struck off to a uniform volume by use of a windrow proportioner or other approved means. If additional mixing is required when travel plants are used this shall be accomplished by means of additional passes of the machine or by blading and pulvi-mixing.

(d) When Central Mixing Plant is used, the plant shall be so constructed to allow the accurate proportioning of soil, admixture if any, and asphalt in accordance with the directions of the Engineer, and the whole being mixed until a homogeneous material is obtained.

(3) Aerating: (a) When the bituminous material used is a cutback type or an emulsion, the mixed material will require considerable manipulation to aerate and reduce the total liquid content of volatile oils and water. The Engineer shall be the sole judge of when the material has had sufficient aeration and the period required may vary considerably depending on the moisture content at the time of mixing, the type of bituminous material used, and the weather conditions.

(b) The Engineer may direct that material which has not had sufficient aeration be windrowed at the end of each days work or when weather conditions warrant.

(4) Compaction of Soil-Asphalt Stabilized Base Course:

(a) After the mixture has been approved by the Engineer it shall be spread, shaped and compacted to the density specified by the Engineer., by means of approved equipment. No mixture shall be spread on the subgrade if, in the opinion of the Engineer, conditions are not suitable. Compaction may be limited to three inch lifts of mixed material, with the excess material being windrowed. The last lift should be a minimum depth of two inches. The sheepsfoot roller marks shall be left between the lower lifts in order to avoid cleavage planes between the lifts. If weather conditions are such that raw sand is deposited by the wind over the compacted lower lifts, it will be necessary to tight blade the top surface of the lift before the next lift is spread. Compaction of the final lift shall be by means of straight axle pneumatic tired rollers.

(b) Variations such as depressions, high areas, or failures which may develop during rolling operations, shall be corrected by re-shaping and re-compaction. Lean or fat areas may be directed by the Engineer to be removed and replaced with new processed material. All corrections shall be as directed by the Engineer and without compensation to the Contractor.

(c) When final rolling and finishing has been completed the Constractor shall be required to apply a bituminous fog seal as directed by the Engineer.

(d) The Contractor is responsible for the maintenance of the subgrade. When trimming is required due to the Contractors operations such work shall be carried out by the Contractor without compensation. Notwithstanding the General Specifications if repairs to the subgrade are necessitated by other than the Contractors operations, such repairs shall be paid for as extra work.

7. Method of Measurement:

(1) "Soil-Asphalt Stabilized Base Course" shall be measured in square yards. The area in square yards of base course completed and accepted shall be derived from measurements made by the Engineer.

(2) "Supplying, Hauling and Compacting New Material" shall be measured by cubic yards of material delivered to the road. Where trucks are used for hauling, measurement shall be based on the water level capacity of the truck box as measured by the Engineer to the nearest one-tenth cubic yard. Where earth moving equipment is used the method of measurement will be by embankment quantities measured in cubic yards.

(3) "Water" used for the adjustment of the moisture content of the soil prior to the bituminous application and water for compaction of new material not requiring processing with bitumen shall be measured in units of one thousand (1,000) Imperial gallons and shall be measured as delivered in previously calibrated tanks or by another method satisfactory to the Engineer.

(4) "Spraying Asphalt" shall be measured by volume of bituminous material in Imperial gallons at 60 degrees Fahrenheit and shall include only cuch material applied to the road for prime coats and fog seals. This shall not include bituminous materials used in the mixing operations for soil-asphalt stabilized base course.

8. Basis of Payment:

(1) "Soil-Asphalt Stabilized Base Course" will be paid for at the unit price per square yard, as set forth in the contract, and will be payment in full for heating, distributing and mixing bituminous material and the aerating, spreading and compaction of the mixed material and the performance of all operations pertaining thereto, as described herein, and those operations incidental to the work.

(2) "Supplying, Hauling and Compacting New Material" will be paid for at the unit price per cubic yard as set forth in the contract and it will be payment in full for supplying, hauling, spreading, and compacting the material, and performing the operations pertaining thereto, as herein described and those operations incidental to the work.

(3) "Water" will be paid for at the contract unit price of one thousand (1,000) Imperial gallons which price shall include the cost of supplying, hauling and distributing same and the performance of all operations pertaining thereto, as herein described and those operations incidental to the work.

(4) "Spraying Asphalt" will be paid for at the unit price per Imperial gallon as set forth in the contract and it will be payment in full for the performance of all operations pertaining thereto, as herein described and those operations incidental to the work.

Identified as the Specifications for the Construction of a Soil-Asphalt Stabilized Base Course pertaining to the work under this Contract.

APPENDIX "B"

PRELIMINARY TESTING

Specific Gravity

Sieve Analyses

Standard AASHO Density Determination

Moisture-Density Relationship for Static Compaction

Analysis of Silt (Used as a Secondary Additive)

Drained Triaxial Test on Marchand Sand

UNIVERSITY of ALBERTA
DEP'T. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

SPECIFIC GRAVITY

PROJECT	Marchand
SITE	PTH No. 52
SAMPLE	Fine Sand
LOCATION	
HOLE	DEPTH 1.0'
TECHNICIAN J.A.K.	DATE 9-5-61

Sample No.	1	2
Flask No.	101	103
Method of Air Removal	Vacuum + Boiling	Vacuum + Boiling
W_{b+w+s}	153.223	159.488
Temperature T	26.2°C	27.8°C
W_{b+w}	135.719	141.192
Evaporating Dish No.	101	103
Wt. Sample Dry + Dish	64.313	71.081
Tare Dish	36.176	41.664
W_s	28.237	29.417
G_s	2.622	2.636

W_{b+w+s} = Weight of flask + water + sample at T°.
W_{b+w} = Weight of flask + water at T° (flask calibration curve).
W_s = Weight of dry soil
G_s = Specific gravity of soil particles = $\dfrac{W_s}{W_s + W_{b+w} - W_{b+w+s}}$

Determination of W_s from wet soil sample:

Sample No.			Sample No.		
Container No.			Container No.		
Wt. Sample Wet + Tare			Wt. Test Sample Wet + Tare		
Wt. Sample Dry + Tare			Tare Container		
Wt. Water			Wt. Test Sample Wet		
Tare Container			W_s		
Wt. of Dry Soil					
Moisture Content w %					

Description of Sample:

Fine Sand --- A-3(0)

Remarks: Average Specific Gravity = 2.63

PROVINCE OF MANITOBA
DEPARTMENT OF PUBLIC WORKS
HIGHWAYS BRANCH
Materials and Research Section

TYPICAL SIEVE ANALYSIS OF MARCHAND SAND

% Passing

Sieve										Average
No. 10	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
No. 40	98.5	99.0	99.0	98.5	99.0	99.0	96.5	96.5	97.0	98.1
No. 80	58.5	72.0	67.0	61.5	59.0	60.0	70.0	70.5	69.5	68.0
No. 100	25.0	38.5	33.0	23.5	30.0	24.5	54.5	35.0	37.5	33.5
No. 200	2.0	3.0	3.0	2.5	3.0	2.5	3.5	4.0	3.5	3.0

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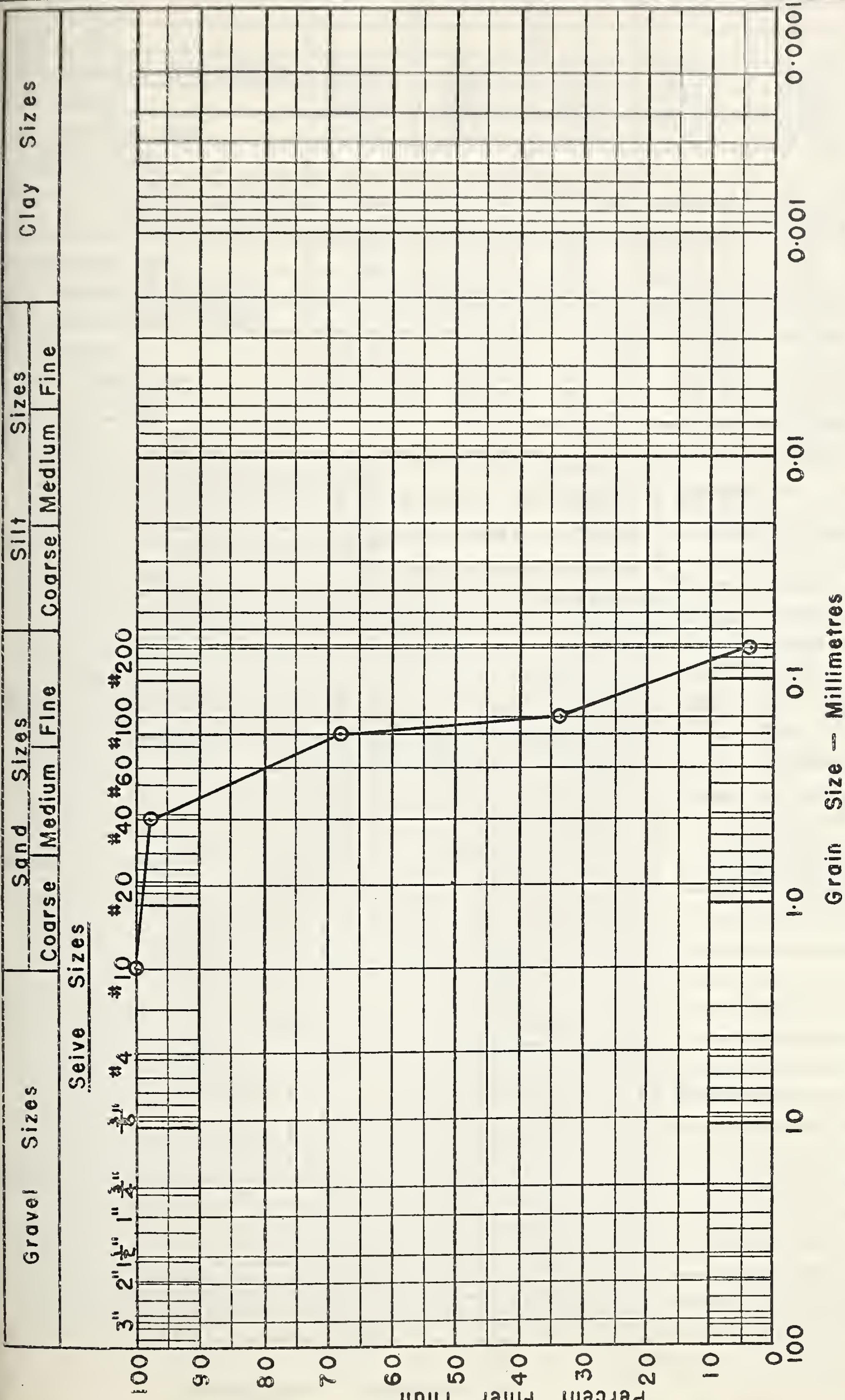
SOIL MECHANICS LABORATORY

GRAIN SIZE CURVE

PROJECT	Marchand		
SITE	PTH No. 52		
SAMPLE	Fine Sand		
LOCATION			
HOLE		DEPTH	-1'
TECHNICIAN	J.A.K.	DATE	25-5-61



D_{10} = 0.083 mm.
D_{60} = 0.170 mm.
C_u 2.05

Remarks: The above curve shows the gradation of the sand used in the sand-asphalt stabilization project. The gradation shown is the average of nine sieve analysis.

Note: M.I.T. Grain Size Scale

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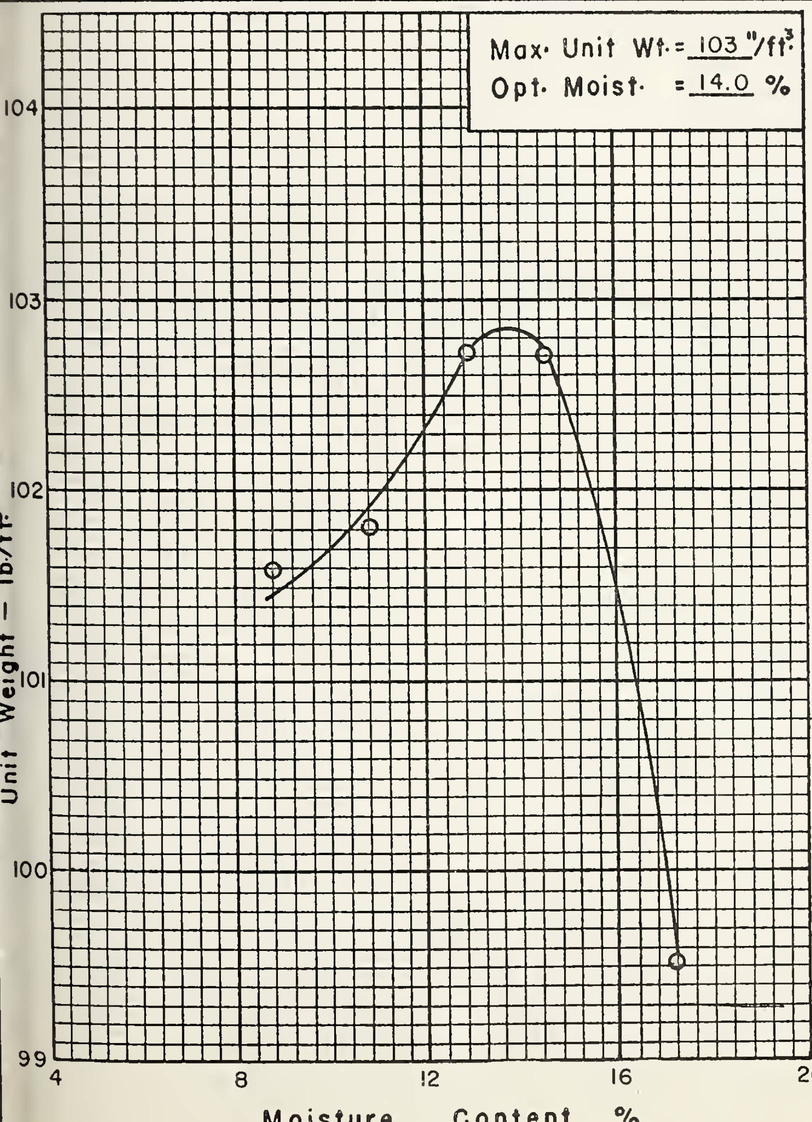
SOIL MECHANICS LABORATORY
COMPACTION TEST

PROJECT	Marchand
SITE	PTH No. 52
SAMPLE	Fine Sand
LOCATION	
HOLE	DEPTH 1.0'
TECHNICIAN J.A.K.	DATE 29-5-61

Trial Number							
Unit Weight Determination							
Mold No.							
Wt. Sample Wet + Mold	3606	3642	3720	3757	3803	3828	3813
Wt. Mold	2050	2050	2050	2050	2050	2050	2050
Wt. Sample Wet	1556	1592	1670	1707	1753	1778	1763
Volume Mold							
Wet Unit Weight lb./ft.^{3}	102.9	105.3	110.5	112.9	115.9	117.6	116.6
Dry Unit Weight lb./ft.^{3}	100.8	101.5	101.6	101.8	102.7	102.7	99.5
Moisture Content Determination							
Container No.	66	108	94	13	33	41	121
Wt. Sample Wet + Tare	133.7	139.4	157.0	129.8	129.9	122.4	143.1
Wt. Sample Dry + Tare	132.2	136.6	149.1	123.0	121.7	114.3	130.4
Wt. Water	1.5	2.8	7.9	6.8	8.2	8.1	12.7
Tare Container	58.9	60.9	59.1	59.3	58.4	58.2	56.9
Wt. Dry Soil	73.3	75.7	90.0	63.7	63.3	56.1	73.7
Moisture Content (%)	2.1	3.7	8.8	10.8	12.9	14.5	17.2



Method of Compaction: Standard AASHO

Diam. Mold: 4.00 inches
Height Mold: 4.00 inches
Volume Mold: 1/30 ft^3
No. of Layers: 3
Blows per Layer: 25
Ht. of Free Fall: 12 inches
Wt. of Tamper: 5.5 pounds
Shape of Tamping Face: Ø
Description of Sample: Fine Sand
AASHO Classification -- A-3(0)

Remarks

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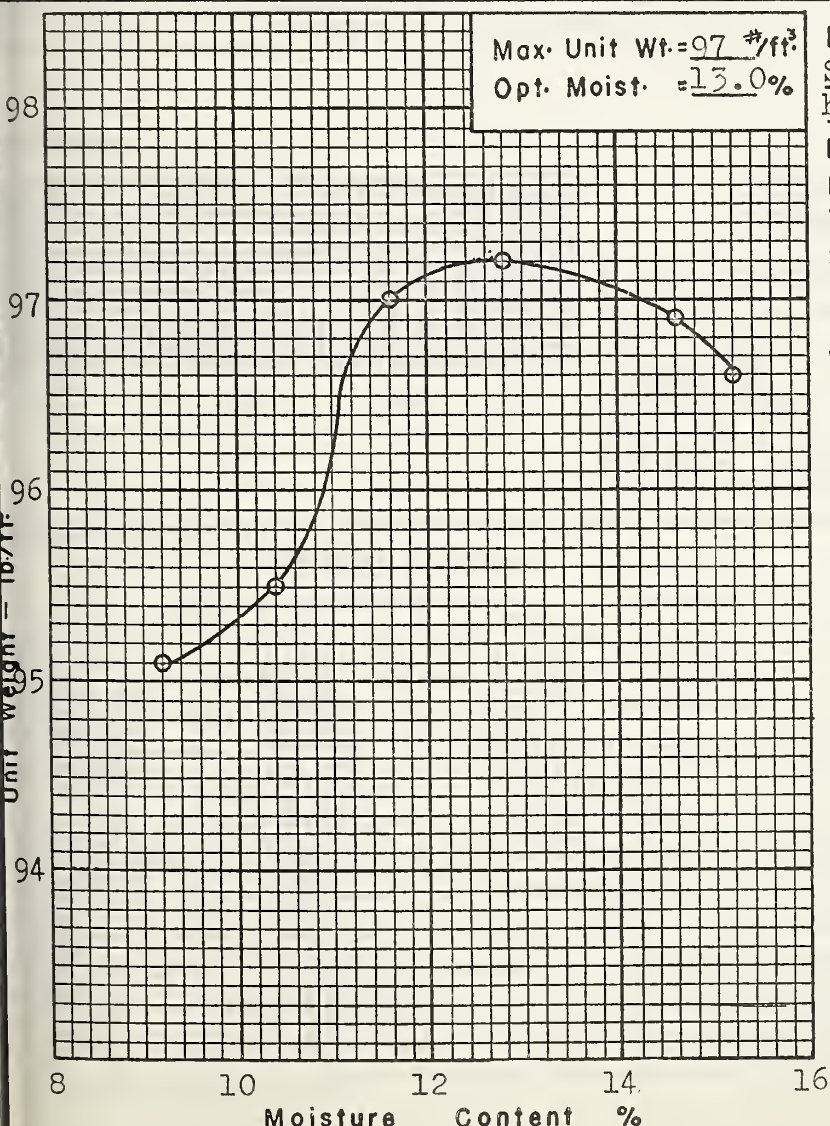
SOIL MECHANICS LABORATORY
COMPACTION TEST

PROJECT	Marchand		
SITE	PTH No. 52		
SAMPLE	Fine Sand		
LOCATION			
HOLE		DEPTH	-1'
TECHNICIAN	J.A.K.	DATE	29-5-61

	Trial Number	1	2	3	4	5	6	
Unit Weight Determination	Mold No.							
	Wt. Sample Wet + Mold	1447	1454	1465	1471	1477	1478	
	Wt. Mold	1018	1018	1018	1018	1018	1018	
	Wt. Sample Wet	429	436	447	453	459	460	
	Volume Mold							
	Wet Unit Weight lb./ft^3	103.8	105.5	108.2	109.6	111.1	111.3	
	Dry Unit Weight lb./ft^3	95.1	95.5	97.0	97.2	96.9	96.6	
Moisture Content Determination	Container No.	1	2	3	4	5	6	
	Wt. Sample Wet + ~~Tare~~	426	434	443	450	456	456	
	Wt. Sample Dry + ~~Tare~~	390	393	397	399	398	396	
	Wt. Water	36	41	46	51	58	60	
	Tare Container							
	Wt. Dry Soil							
	Moisture Content (%)	9.2	10.4	11.6	12.8	14.6	15.2	



Method of Compaction
Static Load of 5000 lbs. held for 1 minute

Diam. Mold 2.00 inches
Height Mold 5.00 inches
Volume Mold 0.00909 in³
No. of Layers one
Blows per Layer ---
Ht. of Free Fall ---
Wt. of Tamper ---
Shape of Tamping Face Ø
Description of Sample
Fine Sand
AASHO Classification
-- A-3(0)

Remarks

PW—HD—286 R2

MANITOBA HIGHWAYS BRANCH
MATERIALS TESTING LABORATORY

SOIL SAMPLE WORK SHEET

E	22-11-61	LAB. No.
ATION		
	Sample of mineral filler material for use in Marchand sand-asphalt stabilization investigation.	

MECHANICAL ANALYSIS

SED. in MIN.	HYD. READING	MM SIZE	K_N x SIZE	TAG	GRAMS	%		TOTAL SAMPLE
				+ 40			C. A. % RET. No. 10	0
				− 40			C. S. % RET. No. 40	0
				TOTAL			FINE SAND	5.0
							SILT	71.0
P.	HR						CLAY	24.0
C	ΔT	PLUS		No. 10			− 40 FACTOR	
	HCR	200 SAND−		No. 40				
							TOTAL SAMPLE PASS No. 200	95.0

IN SIZE CURVE

N .004 .005 .006 .007
M

COLOUR

TEXTURAL CLASS Silty Clay Loam

1.	Pass No. 200	−35 =	A (max. 40) X .2 =	8.0
2.	L. L.	−40 =	C (max. 20) X .005 A =	0
3.	Pass No. 200	−15 =	B (max. 40)	0
4.	P. I.	−10 =	D (max. 30) X .01 B =	0
Classification		A-4(8)	Group Index	8.0

PHYSICAL ANALYSIS

	L. L.	P. L.		REMARKS
TLE No.	A-17	A-20		
TLE + WET SOIL	66.91	63.04		
TLE + DRY SOIL	61.81	59.68		
GHT OF BOTTLE	42.97	43.73		
S	5.10	3.36		
GHT OF DRY SOIL	18.84	15.95		
CENT MOISTURE	27.1	21.1		
SHOCKS	17			
FACTOR	0.952			
UID LIMIT	26			
STIC LIMIT	21			
P. I.	5			

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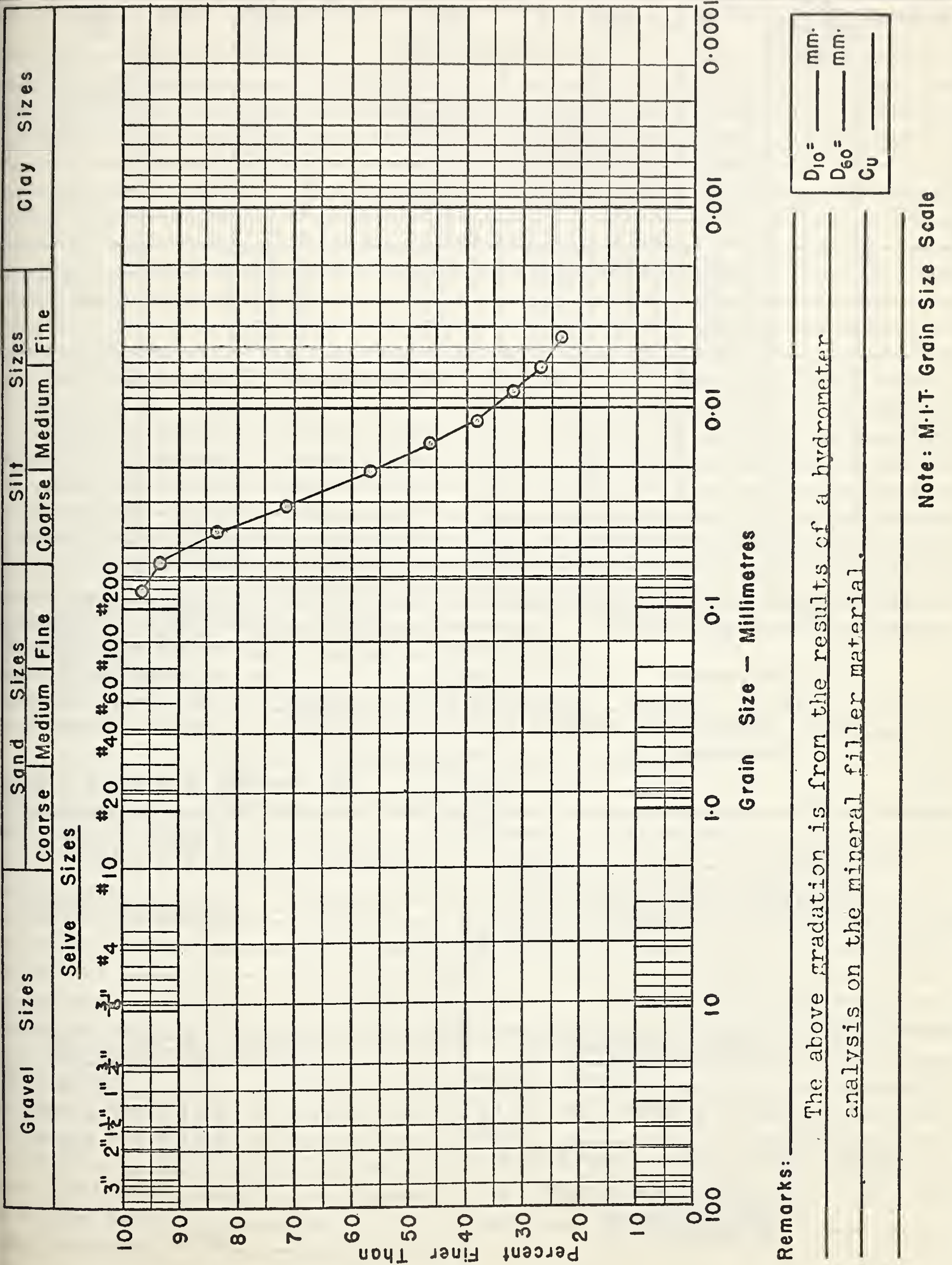
SOIL MECHANICS LABORATORY
GRAIN SIZE CURVE

PROJECT	Marchand		
SITE	PTH No. 52		
SAMPLE	Mineral Filler		
LOCATION			
HOLE		DEPTH	
TECHNICIAN	J.A.K.	DATE	11-12-61



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SOIL MECHANICS LABORATORY

HYDROMETER TEST

PROJECT	Marchand
SITE	PTH No. 52
SAMPLE	Mineral Filler
LOCATION	
HOLE	DEPTH
TECHNICIAN J.A.K.	DATE 11-12-61

Date	Temp· °C	Time	Elapsed Time	R_h'	$R_h = R_h' + c_m$	D m.m.	$R_h + m_t - c_d$	W %	W % Basis Orig. Sample	Remarks
	20.7		15 s		49.0	0.081	48.5	97.0		
			30 s		47.0	0.058	46.5	93.0		
			60 s		42.0	0.043	41.5	83.0		
			2 m		36.0	0.032	35.5	71.0		
			4 m		29.0	.0217	28.5	57.0		
			8 m		23.5	.0160	23.0	46.0		
			15 m		19.5	.0118	19.0	38.0		
			30 m		16.5	.0085	16.0	32.0		
			60 m		14.0	.0062	13.5	27.0		
			120 m		12.0	.0044	11.5	23.0		

Hydrometer No.s 3806 - D and ________ Graduate No. 13

$W\% = \frac{100}{W_s} \cdot \frac{S_s}{S_s - 1} (R_h + m_t - c_d) =$ 2.00 $(R_h + m_t - c_d)$

Meniscus correction = c_m = 1.0 and ________ respectively

Dispersing agent used Calgon -- 6% Solution Amount 30 cc

Correction for change in density of liquid due to addition of dispersing agent = c_d

c_d = 0.5 and ________ respectively

Specific Gravity of Solids = G_s 2.71

Description of Sample
Mineral Filler Material

Silty Clay Loam -- A-4(8)

Method of Preparation
Mineral filler, calgon, and water allowed to sit for 18 hours before testing

Remarks

Initial Moisture Content

Container No. ________
Wt. Sample Wet + Tare ________
Wt. Sample Dry + Tare ________
Wt. Water ________
Tare Container ________
Wt. of Dry Soil ________
Initial Moisture w % ________

Dry Weight of Sample

Container No. ________
Wt. Sample (Wet/Dry) + Tare ________
Tare ________
Wt. (~~Wet~~/Dry) Soil 50.00 grams
Dry Weight from Initial
Moisture = $\frac{100 \times \text{Wt. Wet Soil}}{100 + \text{Init. Moist. \%}}$ = ________

TRIAXIAL COMPRESSION TEST

Lab. No. ____________

Highway's Testing Laboratory
1760 Pembina Highway
WINNIPEG 9, Manitoba

Project: Marchand
Test for J.A. Knowles
Address ____________

ample No. 1 Test hole no. ______ Depth (ft.) 1.0
onfining pressure psi 10.0 Wt. of piston & loading cap lb. 0.5
ample description: Fine Sand --- A-3(0)
omments: Rate of Strain (E-1) --- 0.010 inches per minute

Load Dial Reading x 0.24 = Load in Pounds

oad ~~xxx~~ Dial	Strain Dial inches	Total Strain inches	Unit Strain inches	1-Unit Strain inches	Corrected Area Sq.inches	Deviator Stress psi	Vertical Stress psi
0	0						
15	20						
70	40						
95	60						
10	80						
19	100						
31	120						
37	140						
41	160						
14	180						
17	200	0.200	0.040	0.960	3.27	25.5	35.5
19	220	0.220	0.044	0.956	3.29	25.5	35.5
54	260						
50	300						
55	350						
70	400						

MPLE DIMENSIONS Inches

ameter, Top	
Middle	
Bottom	
Average	2.00"
erage Height	5.00"

SKETCH AT FAILURE

MOISTURE CONTENTS	START	END
Container No		20
Wt.Container & Moist sample-gm		596.0
Wt.Container & Dry sample---gm		562.0
Wt. Container---------------gm		180.0
Wt. Moist sample------------gm	414.0	416.0
Wt. Moisture----------------gm		34.0
Wt. Dry sample--------------gm	380.0	382.0
Moisture content------------ %	8.9	8.9

Specific gravity 2.63 From Test ~~Assumed~~
Volume of sample--------cc 257.4 cu.in. 15.71
Volume of Soil Solids--cc 144.5
Volume of Voids--------cc 112.9 Void
Degree of Saturation--- % 3.0 Ratio 0.781
Density ____________ Dry 92.0 pcf Moist ____ pcf
100.2

ested by:	Date:	Computed by:	Date:	Checked by:	Date:
J.A.K.	2-6-61	J.A.K.	5-6-61	P.D.	5-12

TRIAXIAL COMPRESSION TEST Lab. No.

Highway's Testing Laboratory
1760 Pembina Highway
WINNIPEG 9, Manitoba

Project: Marchand
Test for J.A. Knowles
Address

Sample No. 2 Test hole no. Depth (ft.) 1.0
Confining pressure psi 20.0 Wt. of piston & loading cap lb. 0.5
Sample description: Fine Sand --- A-3(0)
Comments: Rate of Strain (E-1) --- 0.010 inches per minute

Load Dial Reading x 0.24 = Load in Pounds

Load ~~lbs~~ Dial	Strain Dial inches	Total Strain inches	Unit Strain inches	1-Unit Strain inches	Corrected Area Sq.inches	Deviator Stress psi	Vertical Stress psi
0	0						
340	20						
472	40						
541	60						
578	80						
601	100						
618	120						
630	140						
641	160						
651	180						
659	200	0.200	0.040	0.960	3.27	48.4	68.4
665	220						
675	250						
687	300						
700	350						

AMPLE DIMENSIONS	Inches
iameter, Top	
Middle	
Bottom	
Average	2.00"
verage Height	5.00"

SKETCH AT FAILURE

MOISTURE CONTENTS	START	END
Container No		W
Wt.Container & Moist sample-gm		593.0
Wt.Container & Dry sample---gm		556.0
Wt. Container---------------gm		174.0
Wt. Moist sample------------gm	422.0	419.0
Wt. Moisture----------------gm		37.0
Wt. Dry sample--------------gm	384.0	382.0
Moisture content------------ %	9.7	9.7

Specific gravity 2.63 From Test ~~Assumed~~
Volume of sample--------cc 257.4 cu.in.
Volume of Soil Solids--cc 146.0
Volume of Voids---------cc 111.4 Void
Degree of Saturation--- % 3.3 Ratio 0.763
Density Dry 92.9 pcf Moist pcf
102.1

Tested by:	Date:	Computed by:	Date:	Checked by:	Date:
J.A.K.	2-6-61	J.A.K.	5-6-61	P.D.	5-12-

TRIAXIAL COMPRESSION TEST Lab. No.

Highway's Testing Laboratory
1760 Pembina Highway
WINNIPEG 9, Manitoba

Project: Marchand
Test for J.A. Knowles
Address

Sample No. 3 Test hole no. Depth (ft.) 1.0
Confining pressure psi 30.0 Wt. of piston & loading cap lb. 0.5
Sample description: Fine Sand --- A-3(0)
Comments: Rate of Strain (E-1) --- 0.010 inches per minute
Load Dial Reading x 0.24 = Load in Pounds

Load ~~lbs~~ Dial	Strain Dial inches	Total Strain inches	Unit Strain inches	1-Unit Strain inches	Corrected Area Sq.inches	Deviator Stress psi	Vertical Stress psi
0	0						
262	10						
467	20						
600	30						
670	40						
719	50						
752	60						
798	80						
827	100						
850	120						
870	140						
889	160						
905	180						
920	200	0.200	0.040	0.960	3.27	67.5	97.5
927	210						

AMPLE DIMENSIONS Inches
iameter, Top
Middle
Bottom
Average 2.00"
verage Height 5.00"

SKETCH AT FAILURE

MOISTURE CONTENTS	START	END
Container No		2
Wt.Container & Moist sample-gm		671.0
Wt.Container & Dry sample---gm		632.0
Wt. Container---------------gm		244.5
Wt. Moist sample------------gm	427.5	426.5
Wt. Moisture----------------gm		39.0
Wt. Dry sample--------------gm	388.6	387.5
Moisture content------------ %	10.0	10.0

Specific gravity 2.63 From Test ~~Assumed~~
Volume of sample--------cc 257.4 cu.in.
Volume of Soil Solids--cc 147.8
Volume of Voids---------cc 109.6 Void
Degree of Saturation--- % 3.6 Ratio 0.742
Density Dry 94.0 pcf Moist 103.5 pcf

Tested by:	Date:	Computed by:	Date:	Checked by:	Date:
J.A.K.	2-6-61	J.A.K.	5-6-61	P.D.	5-12-61

TRIAXIAL COMPRESSION TEST Lab. No.

Highway's Testing Laboratory
1760 Pembina Highway
WINNIPEG 9, Manitoba

Project: Marchand
Test for J.A. Knowles
Address

Sample No. 4 Test hole no. Depth (ft.) 1.0
Confining pressure psi 38.5 Wt. of piston & loading cap lb. 0.5
Sample description: Fine Sand --- A-3(0)
Comments: Rate of Strain (E-1) --- 0.010 inches per minute
Load Dial Reading x 0.24 = Load in Pounds

Load Dial	Strain Dial inches	Total Strain inches	Unit Strain inches	1-Unit Strain inches	Corrected Area Sq.inches	Deviator Stress psi	Vertical Stress psi
0	0						
451	20						
710	35						
831	50						
927	70						
1020	90						
1059	110						
1079	140						
1096	160						
1116	180						
1134	200	0.200	0.040	0.960	3.27	83.2	121.7
1147	220						
1163	240						
1193	300						
1257	400						

SAMPLE DIMENSIONS Inches

Diameter, Top	
Middle	
Bottom	
Average	2.00"
Average Height	5.00"

SKETCH AT FAILURE

MOISTURE CONTENTS	START	END
Container No		101
Wt. Container & Moist sample-gm		593.0
Wt. Container & Dry sample---gm		562.5
Wt. Container---------------gm		181.5
Wt. Moist sample------------gm	413.5	411.5
Wt. Moisture----------------gm		30.5
Wt. Dry sample--------------gm	382.9	381.0
Moisture content------------ %	8.0	8.0

Specific gravity 2.63 From Test ~~Assumed~~
Volume of sample--------cc 257.4 cu.in.
Volume of Soil Solids--cc 145.6
Volume of Voids---------cc 111.8 Void
Degree of Saturation--- % 2.7 Ratio 0.768
Density Dry 92.7 pcf Moist pcf
100.0

Tested by:	Date:	Computed by:	Date:	Checked by:	Date:
J.A.K.	2-6-61	J.A.K.	5-6-61	P.D.	5-12-61

TRIAXIAL COMPRESSION TEST Lab. No.

Highway's Testing Laboratory
1760 Pembina Highway
WINNIPEG 9, Manitoba

Project: Marchand

Test for J.A. Knowles

Address

Sample No. 5 Test hole no. Depth (ft.) 1.0
Confining pressure psi 50.0 Wt. of piston & loading cap lb. 0.5
Sample description: Fine Sand --- A-3(0)
Comments: Rate of Strain (E-1) --- 0.010 inches per minute
Load Dial Reading x 0.24 = Load in Pounds

Load ~~lbs.~~ Dial	Strain Dial inches	Total Strain inches	Unit Strain inches	1-Unit Strain inches	Corrected Area Sq.inches	Deviator Stress psi	Vertical Stress psi
0	0						
500	20						
770	30						
950	40						
1075	50						
1225	70						
1313	90						
1374	110						
1418	130						
1454	150						
1500	180						
1525	200	0.200	0.040	0.960	3.27	111.9	161.9
1539	220						
1552	240						
1569	270						
1589	300						

SAMPLE DIMENSIONS Inches

Diameter, Top	
Middle	
Bottom	
Average	2.00"
Average Height	5.00"

SKETCH AT FAILURE

MOISTURE CONTENTS	START	END
Container No		20
Wt.Container & Moist sample-gm		589.5
Wt.Container & Dry sample---gm		565.0
Wt. Container---------------gm		180.0
Wt. Moist sample------------gm	405.5	409.5
Wt. Moisture----------------gm		24.5
Wt. Dry sample--------------gm	381.2	385.0
Moisture content------------ %	6.4	6.4

Specific gravity 2.63 From Test ~~Assumed~~
Volume of sample--------cc 257.4 cu.in.
Volume of Soil Solids--cc 144.9
Volume of Voids--------cc 112.5 Void
Degree of Saturation--- % 2.2 Ratio 0.776
Density Dry 92.3 pcf Moist pcf
98.1

Tested by:	Date:	Computed by:	Date:	Checked by:	Date:
J.A.K.	2-6-61	J.A.K.	5-6-61	P.D.	5-12-61

APPENDIX "C"

METHOD OF CALCULATION

Method of Calculating Void Properties

Stress Computation Chart

Weight-Density Charts

Void Calculation Chart

Weight of Asphalt Added for Various Sample Weights

Weight of Asphalt and Lime Added (1 per cent Lime)

Weight of Asphalt and Lime Added (3 per cent Lime)

METHOD OF CALCULATING VOID PROPERTIES

The following method of calculating the void properties of the statically compacted 2-inch by 5-inch unconfined compression samples was used throughout this investigation.

The volumes of approximately 90 samples were measured by the water displacement method with the weights being taken to the nearest 0.1 grams. It was found that the average volume of the sample was 255.0 cubic centimeters, with a maximum deviation from this average volume of 3.0 cubic centimeters.

Assuming an error of 0.02 inches in the measurement of the height and the diameter of the specimens, the resultant error in the volume of the sample is 3.6 cubic centimeters. Since this experimental error was larger than the maximum deviation from the average volume, the volumes of all samples were assumed to be 255.0 cubic centimeters for the purpose of calculating the void properties.

The following general method of performing the calculations will offer an explanation of some of the terms used in the body of this report.

(1) Weight of Materials Added =

$$= \text{Dry Sample Weight} - \frac{\text{Dry Sample Weight}}{1 + A\%} \times 100$$

Where:

A = Total percentage of materials added

= B + C

B = Per cent of asphalt added

C = Per cent of lime added

(2) Weight of Soil Solids =

= Weight of Dry Sample - Weight of Additives

(3) Weight of Water =

= Weight of Wet Sample - Weight of Dry Sample

(4) Volume of Soil Solids =

$$= \frac{\text{Dry Sample Weight} - \text{Weight of Additives}}{\text{Specific Gravity of Soil Solids}}$$

(5) Volume of Voids in Aggregate =

= Volume of Sample - Volume of Soil Solids

(6) Per Cent Voids in Aggregate Filled with Asphalt =

$$= \frac{\dfrac{\text{Weight of Asphalt}}{\text{Specific Gravity of Asphalt}}}{\text{Volume of Voids}} \times 100$$

(7) Per Cent Voids in the Aggregate Filled with Lime =

$$= \frac{\dfrac{\text{Weight of Lime}}{\text{Specific Gravity of Lime}}}{\text{Volume of Voids}} \times 100$$

(8) Per Cent Voids in Aggregate Filled with Water =

$$= \frac{\dfrac{\text{Weight of Water}}{\text{Specific Gravity of Water}}}{\text{Volume of Voids}} \times 100$$

(9) Per Cent Voids in the Aggregate =

$$= \frac{\text{Volume of Voids in Aggregate}}{\text{Total Volume of Sample}} \times 100$$

(10) Per Cent Voids in the Mix =

$$= \frac{\text{Volume of Voids in Aggregate} - \text{Volume of Additives}}{\text{Total Volume of Sample}} \times 100$$

STRESS COMPUTATION TABLE

Soiltest Motorized Unconfined Compression Machine Model U-164
Proving Ring No. 2133
2.00" diameter by 5.00" high samples

Corr. Area Strain Dial	3.16 20-35	3.17 40-50	3.18 55-65	3.19 70-80	3.20 85-95	3.21 100-110	3.22 115-125
Load Dial							
10	1.02	1.01	1.01	1.01	1.00	1.00	0.99
15	1.52	1.52	1.51	1.51	1.50	1.50	1.49
20	2.03	2.02	2.02	2.01	2.00	2.00	1.99
25	2.53	2.53	2.52	2.51	2.50	2.50	2.49
30	3.04	3.03	3.03	3.02	3.01	3.00	2.99
35	3.55	3.54	3.53	3.52	3.51	3.50	3.48
40	4.06	4.04	4.03	4.02	4.01	3.99	3.98
45	4.56	4.55	4.53	4.52	4.51	4.49	4.48
50	5.07	5.06	5.04	5.03	5.01	4.99	4.98
55	5.58	5.56	5.54	5.53	5.51	5.49	5.47
60	6.09	6.07	6.05	6.03	6.01	5.99	5.97
65	6.59	6.57	6.55	6.53	6.51	6.49	6.47
70	7.10	7.08	7.06	7.03	7.01	6.99	6.97
75	7.61	7.58	7.56	7.54	7.51	7.49	7.47
80	8.11	8.09	8.06	8.04	8.01	7.99	7.96
85	8.62	8.59	8.57	8.54	8.51	8.49	8.46
90	9.13	9.10	9.07	9.04	9.02	8.99	8.96
95	9.64	9.61	9.58	9.55	9.52	9.49	9.46
100	10.14	10.11	10.08	10.05	10.02	9.98	9.95
105	10.65	10.62	10.58	10.55	10.52	10.48	10.45
110	11.16	11.12	11.08	11.05	11.02	10.98	10.95
115	11.66	11.63	11.59	11.55	11.52	11.48	11.45
120	12.17	12.13	12.09	12.06	12.02	11.98	11.94
125	12.68	12.64	12.60	12.56	12.52	12.48	12.44
130	13.18	13.14	13.10	13.06	13.02	12.98	12.94
135	13.69	13.65	13.61	13.56	13.52	13.48	13.44
140	14.20	14.15	14.11	14.07	14.02	13.98	13.93
145	14.71	14.66	14.61	14.57	14.52	14.48	14.43
150	15.21	15.16	15.12	15.07	15.02	14.98	14.93
155	15.72	15.67	15.62	15.57	15.53	15.48	15.43
160	16.23	16.18	16.13	16.08	16.03	15.97	15.93
165	16.73	16.68	16.63	16.58	16.53	16.47	16.42
170	17.24	17.19	17.13	17.08	17.03	16.97	16.92
175	17.75	17.69	17.64	17.58	17.53	17.47	17.42

WEIGHT - DENSITY CHART

2.00" x 5.00" Samples

Volume: = 15.56 in^3 = 255.0 cc

Multiply Weight in Grams by 0.244 to get pcf.

Grams	pcf	Grams	pcf	Grams	pcf
350	85.4	375	91.5	400	97.6
351	85.6	376	91.7	401	97.8
352	85.9	377	92.0	402	98.1
353	86.1	378	92.2	403	98.3
354	86.4	379	92.5	404	98.6
355	86.6	380	92.7	405	98.8
356	86.9	381	93.0	406	99.1
357	87.1	382	93.2	407	99.3
358	87.4	383	93.5	408	99.6
359	87.6	384	93.7	409	99.8
360	87.8	385	93.9	410	100.0
361	88.1	386	94.2	411	100.3
362	88.3	387	94.4	412	100.5
363	88.6	388	94.7	413	100.8
364	88.8	389	94.9	414	101.0
365	89.1	390	95.2	415	101.3
366	89.3	391	95.4	416	101.5
367	89.5	392	95.6	417	101.7
368	89.8	393	95.9	418	102.0
369	90.0	394	96.1	419	102.2
370	90.3	395	96.4	420	102.5
371	90.5	396	96.6	421	102.7
372	90.8	397	96.9	422	103.0
373	91.0	398	97.1	423	103.2
374	91.3	399	97.4	424	103.5

WEIGHT - DENSITY CHART

2.00" x 5.00" Samples

Volume: = 15.56 in^3 = 255.0 cc

Multiply Weight in Grams by 0.244 to get pcf.

Grams	pcf	Grams	pcf	Grams	pcf
425	103.7	450	109.8	475	115.9
426	103.9	451	110.0	476	116.1
427	104.2	452	110.3	477	116.4
428	104.4	453	110.5	478	116.6
429	104.7	454	110.8	479	116.9
430	104.9	455	111.0	480	117.1
431	105.2	456	111.3	481	117.4
432	105.4	457	111.5	482	117.6
433	105.7	458	111.8	483	117.9
434	105.9	459	112.0	484	118.1
435	106.1	460	112.2	485	118.3
436	106.4	461	112.5	486	118.6
437	106.6	462	112.7	487	118.8
438	106.9	463	113.0	488	119.1
439	107.1	464	113.2	489	119.3
440	107.4	465	113.5	490	119.6
441	107.6	466	113.7		
442	107.8	467	113.9		
443	108.1	468	114.2		
444	108.3	469	114.4		
445	108.6	470	114.7		
446	108.8	471	114.9		
447	109.1	472	115.2		
448	109.3	473	115.4		
449	109.6	474	115.7		

VOID CALCULATION CHART

Specific Gravity of Soil Solids = 2.63

Weight of Soil Solids	Volume of Soil Solids	Volume of Voids	Weight of Soil Solids	Volume of Soil Solids	Volume of Voids
370	140.7	114.3	410	155.9	99.1
371	141.1	113.9	411	156.3	98.7
372	141.4	113.6	412	156.7	98.3
373	141.8	113.2	413	157.0	98.0
374	142.2	112.8	414	157.4	97.6
375	142.6	112.4	415	157.8	97.2
376	143.0	112.0	416	158.2	96.8
377	143.3	111.7	417	158.6	96.4
378	143.7	111.3	418	158.9	96.1
379	144.1	110.9	419	159.3	95.7
380	144.5	110.5	420	159.7	95.3
381	144.9	110.1	421	160.1	94.9
382	145.2	109.8	422	160.5	94.5
383	145.6	109.4	423	160.8	94.2
384	146.0	109.0	424	161.2	93.8
385	146.4	108.6	425	161.6	93.4
386	146.8	108.2	426	162.0	93.0
387	147.1	107.9	427	162.4	92.6
388	147.5	107.5	428	162.7	92.3
389	147.9	107.1	429	163.1	91.9
390	148.3	106.7	430	163.5	91.5
391	148.7	106.3	431	163.9	91.1
392	149.0	106.0	432	164.3	90.7
393	149.4	105.6	433	164.6	90.4
394	149.8	105.2	434	165.0	90.0
395	150.2	104.8	435	165.4	89.6
396	150.6	104.4	436	165.8	89.2
397	150.9	104.1	437	166.2	88.8
398	151.3	103.7	438	166.5	88.5
399	151.7	103.3	439	166.9	88.1
400	152.1	102.9	440	167.3	87.7
401	152.5	102.5	441	167.7	87.3
402	152.8	102.2	442	168.1	86.9
403	153.2	101.8	443	168.4	86.6
404	153.6	101.4	444	168.8	86.2
405	154.0	101.0	445	169.2	85.8
406	154.4	100.6	446	169.6	85.4
407	154.7	100.3	447	170.0	85.0
408	155.1	99.9	448	170.3	84.7
409	155.5	99.5	449	170.7	84.3
			450	171.1	83.9

WEIGHT OF ADDED MATERIALS FOR VARIOUS SAMPLE WEIGHTS

Percentages are per 100 pounds of dry soil

Sample Weight (Gms.)	2% AC	3% AC	4% AC	5% AC	6% AC
400	7.9	11.7	15.4	19.0	22.6
405	8.0	11.8	15.6	19.2	22.9
410	8.1	12.0	15.8	19.5	23.2
415	8.2	12.1	16.0	19.7	23.5
420	8.3	12.3	16.2	20.0	23.8
425	8.4	12.4	16.4	20.2	24.1
430	8.5	12.5	16.5	20.5	24.3
435	8.6	12.7	16.7	20.7	24.6
440	8.7	12.8	16.9	21.0	24.9
445	8.8	13.0	17.1	21.2	25.2
450	8.8	13.1	17.3	21.4	25.5
455	8.9	13.3	17.5	21.7	25.8
460	9.0	13.4	17.7	21.9	26.1
465	9.1	13.6	17.9	22.2	26.4
470	9.2	13.7	18.1	22.4	26.7
475	9.3	13.9	18.3	22.7	27.0
480	9.4	14.0	18.5	22.9	27.2

WEIGHT OF ADDED MATERIALS FOR VARIOUS SAMPLE WEIGHTS

Percentages are per 100 pounds of dry soil

1% Lime Added

Sample Weight (Gms.)	2% AC		3% AC		4% AC		5% AC		6% AC	
	AC	Lime	AC	Lime	AC	Lime	AC	Lime	AC	Lime
400	7.8	3.9	11.5	3.9	15.2	3.8	18.8	3.8	22.5	3.7
405	7.9	3.9	11.7	3.9	15.4	3.8	19.1	3.8	22.7	3.8
410	8.0	4.0	11.8	4.0	15.6	3.9	19.3	3.9	23.0	3.9
415	8.1	4.0	12.0	4.0	15.8	3.9	19.6	3.9	23.3	3.9
420	8.2	4.0	12.1	4.1	16.0	4.0	19.8	4.0	23.5	4.0
425	8.3	4.1	12.2	4.1	16.2	4.0	20.0	4.0	23.8	4.0
430	8.4	4.1	12.4	4.2	16.4	4.1	20.3	4.1	24.1	4.1
435	8.5	4.2	12.5	4.2	16.6	4.1	20.5	4.1	24.4	4.1
440	8.6	4.2	12.7	4.2	16.8	4.1	20.8	4.1	24.7	4.1
445	8.7	4.3	12.8	4.3	17.0	4.2	21.0	4.2	25.0	4.2
450	8.8	4.3	13.0	4.3	17.2	4.2	21.3	4.2	25.2	4.2
455	8.8	4.4	13.1	4.3	17.4	4.2	21.5	4.3	25.5	4.3
460	8.9	4.5	13.3	4.4	17.6	4.3	21.8	4.3	25.8	4.3
465	9.0	4.6	13.5	4.4	17.8	4.3	22.0	4.4	26.1	4.3
470	9.1	4.6	13.6	4.5	18.0	4.4	22.2	4.4	26.3	4.4
475	9.2	4.6	13.7	4.6	18.1	4.5	22.5	4.4	26.6	4.5
480	9.3	4.7	13.9	4.6	18.3	4.6	22.7	4.5	26.9	4.5

WEIGHT OF ADDED MATERIALS FOR VARIOUS SAMPLE WEIGHTS

Percentages are per 100 pounds of dry soil

3% Lime Added

Sample Weight (Gms.)	2% AC		3% AC		4% AC		5% AC		6% AC	
	AC	Lime	AC	Lime	AC	Lime	AC	Lime	AC	Lime
400	7.6	11.4	11.3	11.3	14.9	11.4	18.5	11.2	22.0	11.0
405	7.7	11.5	11.4	11.5	15.1	11.5	18.7	11.3	22.2	11.2
410	7.8	11.7	11.6	11.6	15.3	11.6	19.0	11.3	22.5	11.3
415	7.9	11.8	11.7	11.8	15.5	11.7	19.2	11.5	22.8	11.5
420	8.0	12.0	11.9	11.9	15.7	11.8	19.4	11.7	23.1	11.6
425	8.1	12.1	12.0	12.1	15.9	11.9	19.7	11.8	23.4	11.7
430	8.2	12.2	12.1	12.2	16.1	12.1	19.9	11.9	23.6	11.9
435	8.3	12.4	12.3	12.3	16.3	12.2	20.1	12.1	23.9	12.0
440	8.4	12.5	12.4	12.5	16.5	12.3	20.4	12.2	24.2	12.1
445	8.5	12.7	12.6	12.6	16.7	12.4	20.6	12.4	24.5	12.3
450	8.6	12.8	12.8	12.8	16.8	12.6	20.8	12.6	24.8	12.4
455	8.7	13.0	12.9	12.9	17.0	12.8	21.1	12.7	25.0	12.6
460	8.8	13.1	13.0	13.1	17.2	12.9	21.3	12.8	25.3	12.7
465	8.9	13.3	13.2	13.2	17.4	13.1	21.5	13.0	25.6	12.9
470	9.0	13.4	13.3	13.4	17.6	13.2	21.8	13.1	25.9	13.0
475	9.1	13.5	13.4	13.5	17.8	13.3	22.0	13.3	26.1	13.2
480	9.2	13.7	13.6	13.6	17.9	13.5	22.2	13.4	26.4	13.3

APPENDIX "D"

UNCONFINED COMPRESSION TESTS

Typical Unconfined Compression Work Sheets

Unconfined Compression Summary Sheets

Volume Change Measurements -- Freeze-Thaw Test

Volume Change Measurements -- Water Immersion Test

Amount of Water Absorption -- Water Immersion Test

PROVINCE OF MANITOBA
HIGHWAY'S BRANCH
Materials and Research Section
UNCONFINED COMPRESSION TEST

Project: Marchand
Site: PTH No. 52
Sample No: S-2-3-1 Lab No:
Tested By: J.A.K. Date: Aug. 21

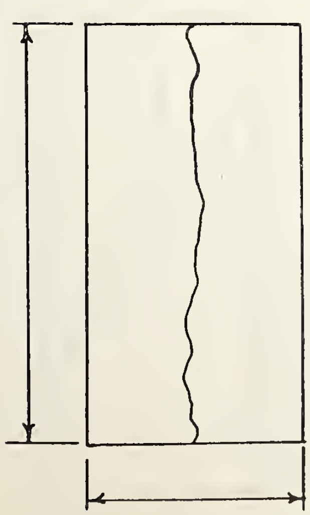
Load Dial	Strain Dial	Total Strain (in)	Unit Strain (μ)	($1 - \mu$)	Corr. Area (in²)	Load lbs	Vertical Stress
0	0						
38	5						
86	10						
119	15						
132	20						
133	25	0.025	0.005	0.995	3.16	42.6	13.48
120	30						
60	40						
10	50						
3	60						

Stabilizing Agent: SS-1 Emulsion Amount: 2 % ______ Gm/Sample
Additive: Lime Amount: 3 % ______ Gm/Sample
Batch Weight: 5000 Gm Mixing Time: 2.0 min. Mixing Water 17 %
Curing Period: Air Dried at Room Temperature

SAMPLE DIMENSIONS

Avg. Diam. 2.00"
Avg. Height 5.00"

SKETCH OF FAILURE



	Moulded	Start	End
Container No:			
Tare + Wet Sample - Gm			
Tare + Dry Sample - Gm			
Tare - Gm			
Wt. wet Sample - Gm	438.5		
Wt. Water - Gm	14.0		
Wt. Dry Sample - Gm	424.5		424.5
Wt. Asphalt - Gm			
Wt. Additive - Gm			
Volatiles - %	3.3		

Specific Gravity:
Volume of Sample: ______ cc. = ______ in³
Volume of Soil Solids: ______ cc. Void
Volume of Voids: ______ cc. Ratio: ____
Degree of Saturation: ______ %
Density: ______ Dry: ______ pcf Wet ______ pcf

REMARKS:

PROVINCE OF MANITOBA
HIGHWAY'S BRANCH
Materials and Research Section
UNCONFINED COMPRESSION TEST

Project: Marchand
Site: PTH No. 52
Sample No: S-3-3-1 Lab No:
Tested By: J.A.K. Date: Aug. 21

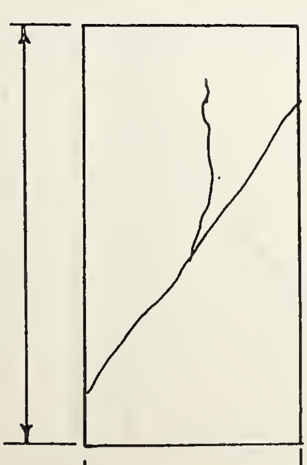
Load Dial	Strain Dial	Total Strain (in)	Unit Strain (μ)	$(1 - \mu)$	Corr. Area (in^2)	Load lbs	Vertical Stress
0	0						
61	10						
108	20						
134	30						
146	40						
148	50	0.050	0.010	0.990	3.17	47.4	14.95
138	60						
121	70						
104	80						
86	90						
70	100						
55	110						
36	120						

Stabilizing Agent: SS-1 Emulsion Amount: 3 % ______ Gm/Sample
Additive: Lime Amount: 3 % ______ Gm/Sample
Batch Weight: 5000 Gm Mixing Time: 2.0 min. Mixing Water 17 %
Curing Period: Air Dried at Room Temperature

SAMPLE DIMENSIONS

Avg. Diam. 2.00"
Avg. Height 5.00"

SKETCH OF FAILURE



	Moulded	Start	End
Container No:			
Tare + Wet Sample - Gm			
Tare + Dry Sample - Gm			
Tare - Gm			
Wt. Wet Sample - Gm	441.0		
Wt. Water - Gm	7.0		
Wt. Dry Sample - Gm	434.0		434.0
Wt. Asphalt - Gm			
Wt. Additive - Gm			
Volatiles - %	1.6		

Specific Gravity: ______
Volume of Sample: ______ cc. = ______ in^3
Volume of Soil Solids: ______ cc. Void
Volume of Voids: ______ cc. Ratio: ______
Degree of Saturation: ______ %
Density: ______ Dry: ______ pcf Wet ______ pcf

REMARKS:

PROVINCE OF MANITOBA
HIGHWAY'S BRANCH
Materials and Research Section
UNCONFINED COMPRESSION TEST

Project: Marchand
Site: PTH No. 52
Sample No: S-4-3-1 Lab No: ______
Tested By: J.A.K. Date: Aug. 21

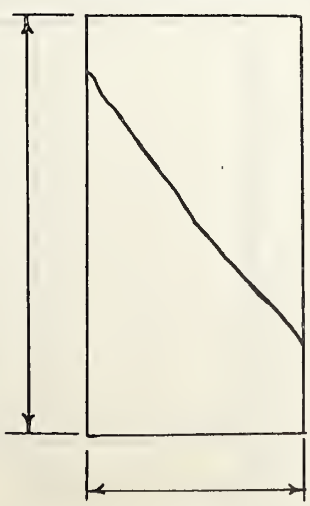
Load Dial	Strain Dial	Total Strain (in)	Unit Strain (μ)	$(1-\mu)$	Corr. Area (in^2)	Load lbs	Vertical Stress
0	0						
51	10						
102	20						
143	30						
171	40						
190	50						
198	60	0.060	0.012	0.0988	3.18	63.5	19.97
197	70						
188	80						
177	90						
161	100						
147	110						
132	120						

Stabilizing Agent: SS-1 Emulsion Amount: 4 % ______ Gm/Sample
Additive: Lime Amount: 3 % ______ Gm/Sample
Batch Weight: 5000 Gm Mixing Time: 2.0 min. Mixing Water 17 %
Curing Period: Air Dried at Room Temperature

SAMPLE DIMENSIONS

Avg. Diam. 2.00"
Avg. Height 5.00"

SKETCH OF FAILURE



	Moulded	Start	End
Container No:			
Tare + Wet Sample - Gm			
Tare + Dry Sample - Gm			
Tare - Gm			
Wt. wet Sample - Gm	452.0		
Wt. Water - Gm	0.0		
Wt. Dry Sample - Gm	452.0		452.0
Wt. Asphalt - Gm			
Wt. Additive - Gm			
Volatiles - %	0		

Specific Gravity: ______
Volume of Sample: ______ cc. = ______ in^3
Volume of Soil Solids: ______ cc. Void
Volume of Voids: ______ cc. Ratio: ______
Degree of Saturation: ______ %
Density: ______ Dry: ______ pcf Wet ______ pcf

REMARKS: ______

PROVINCE OF MANITOBA
HIGHWAY'S BRANCH
Materials and Research Section
UNCONFINED COMPRESSION TEST

Project: Marchand
Site: PTH No. 52
Sample No: S-5-3-1 Lab No:
Tested By: J.A.K. Date: Aug. 21

Load Dial	Strain Dial	Total Strain (in)	Unit Strain (μ)	$(1-\mu)$	Corr. Area (in^2)	Load lbs	Vertical Stress
0	0						
33	10						
75	20						
109	30						
134	40						
154	50						
168	60						
173	70						
174	80	0.080	0.016	0.984	3.19	55.8	17.49
170	90						
162	100						
154	110						
143	120						

Stabilizing Agent: SS-1 Emulsion Amount: 5 % ______ Gm/Sample
Additive: Lime Amount: 3 % ______ Gm/Sample
Batch Weight: 5000 Gm Mixing Time: 2.0 min. Mixing Water 17 %
Curing Period: Air Dried at Room Temperature

SAMPLE DIMENSIONS

Avg. Diam. 2.00"
Avg. Height 5.00"

SKETCH OF FAILURE

	Moulded	Start	End
Container No:			
Tare + Wet Sample - Gm			
Tare + Dry Sample - Gm			
Tare - Gm			
Wt. wet Sample - Gm	469.0		
Wt. Water - Gm	7.0		
Wt. Dry Sample - Gm	462.0		462.0
Wt. Asphalt - Gm			
Wt. Additive - Gm			
Volatiles - %	1.5		

Specific Gravity: ______
Volume of Sample: ______ cc. = ______ in^3
Volume of Soil Solids: ______ cc. Void
Volume of Voids: ______ cc. Ratio: ______
Degree of Saturation: ______ %
Density: ______ Dry: ______ pcf Wet ______ pcf

REMARKS:

PROVINCE OF MANITOBA
HIGHWAY'S BRANCH
Materials and Research Section
UNCONFINED COMPRESSION TEST

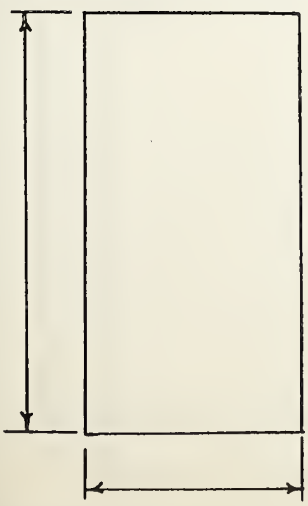
Project: Marchand
Site: PTH No. 52
Sample No: S-6-3-1 Lab No:
Tested By: J.A.K. Date: Aug. 21

Load Dial	Strain Dial	Total Strain (in)	Unit Strain (ϵ)	$(1 - \epsilon)$	Corr. Area (in^2)	Load lbs	Vertical Stress
0	0						
8	5						
20	10						
30	15						
40	20						
49	25						
58	30						
74	40						
90	50						
104	60						
115	70						
123	100	0.100	0.020	0.980	3.21	39.4	12.27
115	120						

Stabilizing Agent: SS-1 Emulsion Amount: 6 % ____ Gm/Sample
Additive: Lime Amount: 3 % ____ Gm/Sample
Batch Weight: 5000 Gm Mixing Time: 2.0 min. Mixing Water 17 %
Curing Period: Air Cured at Room Temperature

SAMPLE DIMENSIONS
Avg. Diam. 2.00"
Avg. Height 5.00"

SKETCH OF FAILURE



	Moulded	Start	End
Container No:			
Tare + Wet Sample - Gm			
Tare + Dry Sample - Gm			
Tare - Gm			
Wt. wet Sample - Gm	463.0		
Wt. Water - Gm	2.5		
Wt. Dry Sample - Gm	460.5		460.5
Wt. Asphalt - Gm			
Wt. Additive - Gm			
Volatiles - %	0.5		

Specific Gravity: 2.63
Volume of Sample: ____ cc. = ____ in^3
Volume of Soil Solids: ____ cc. Void
Volume of Voids: ____ cc. Ratio: ____
Degree of Saturation: ____ %
Density: ____ Dry: ____ pcf Wet ____ pcf
REMARKS:

PROVINCE OF MANITOBA
HIGHWAY'S BRANCH
Materials and Research Section
UNCONFINED COMPRESSION TEST

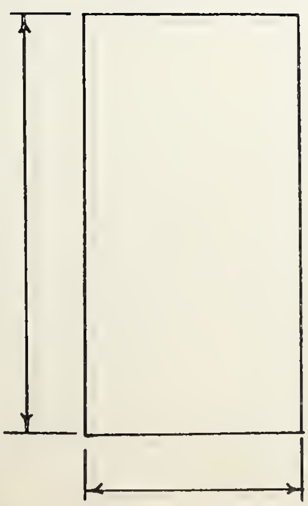
Project: Marchand
Site: PTH No. 52
Sample No: S-5-1-1 Lab No: ______
Tested By: J.A.K. Date: Aug. 21

Load Dial	Strain Dial	Total Strain (in)	Unit Strain (μ)	$(1 - \mu)$	Corr. Area (in^2)	Load lbs	Vertical Stress
0	0						
12	10						
28	20						
39	30						
48	40						
54	50						
59	60						
62	70						
64	80						
65	90	0.090	0.018	0.982	3.20	20.8	6.50
64	100						
63	110						
61	120						

Stabilizing Agent: SS-1 Emulsion Amount: 5 % ______ Gm/Sample
Additive: Lime Amount: 1 % ______ Gm/Sample
Batch Weight: 5000 Gm Mixing Time: 2.0 min. Mixing Water 15 %
Curing Period: Air Dried at Room Temperature

SAMPLE DIMENSIONS
Avg. Diam. 2.00"
Avg. Height 5.00"

SKETCH OF FAILURE



	Moulded	Start	End
Container No:			
Tare + Wet Sample - Gm			
Tare + Dry Sample - Gm			
Tare - Gm			
Wt. wet Sample - Gm	464.0		
Wt. Water - Gm	7.0		
Wt. Dry Sample - Gm	457.0		457.0
Wt. Asphalt - Gm			
Wt. Additive - Gm			
Volatiles - %	1.5		

Specific Gravity: ______
Volume of Sample: ______ cc. = ______ in^3
Volume of Soil Solids: ______ cc. Void
Volume of Voids: ______ cc. Ratio: ______
Degree of Saturation: ______ %
Density: ______ Dry: ______ pcf Wet ______ pcf

REMARKS: ______

PROVINCE OF MANITOBA
HIGHWAY'S BRANCH
Materials and Research Section
UNCONFINED COMPRESSION TEST

Project: Marchand
Site: PTH No. 52
Sample No: S-5-0-1 Lab No:
Tested By: J.A.K. Date: Aug. 21

Load Dial	Strain Dial	Total Strain (in)	Unit Strain (μ)	(1 - μ)	Corr. Area (in²)	Load lbs	Vertical Stress
0	0						
9	10						
19	20						
29	30						
35	40						
39	50						
42	60						
44	70	0.070	0.014	0.0986	3.19	14.1	4.42
44	80						
43	90						
41	100						
39	110						
36	120						

Stabilizing Agent: SS-1 Emulsion Amount: 5 % ______ Gm/Sample
Additive: None Amount: 0 % ______ Gm/Sample
Batch Weight: 5000 Gm Mixing Time: 2.0 min. Mixing Water 14 %
Curing Period: Air Dried at Room Temperature

SAMPLE DIMENSIONS
Avg. Diam. 2.00"
Avg. Height 5.00"

SKETCH OF FAILURE

	Moulded	Start	End
Container No:			
Tare + Wet Sample - Gm			
Tare + Dry Sample - Gm			
Tare - Gm			
Wt. Wet Sample - Gm	448.5		
Wt. Water - Gm	4.5		
Wt. Dry Sample - Gm	444.0		444.0
Wt. Asphalt - Gm			
Wt. Additive - Gm			
Volatiles - %	1.0		

Specific Gravity: ______
Volume of Sample: ______ cc. = ______ in³
Volume of Soil Solids: ______ cc. Void Ratio: ______
Volume of Voids: ______ cc.
Degree of Saturation: ______ %
Density: ______ Dry: ______ pcf Wet ______ pcf

REMARKS:

PROVINCE OF MANITOBA
HIGHWAY'S BRANCH
Materials and Research Section
UNCONFINED COMPRESSION TEST

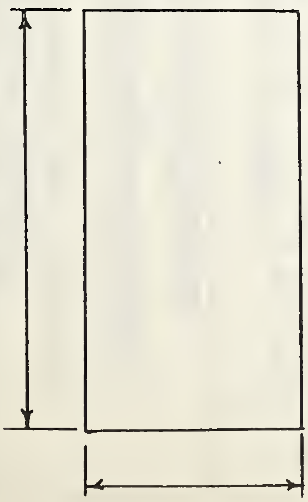
Project: Marchand
Site: PTH No. 52
Sample No: AC-6-3-8 Lab No:
Tested By: J.A.K. Date: Sept. 11

Load Dial	Strain Dial	Total Strain (in)	Unit Strain (μ)	$(1 - \mu)$	Corr. Area (in^2)	Load lbs	Vertical Stress
0	0						
31	10						
48	20						
62	30						
75	40						
88	50						
99	60						
110	70						
118	80						
124	90						
130	100						
141	140	0.140	0.028	0.972	3.23	45.1	13.96
138	170						

Stabilizing Agent: 150-200 Pen. Amount: 6 % ______ Gm/Sample
Additive: Lime Amount: 3 % ______ Gm/Sample
Batch Weight: 5000 Gm Mixing Time: 2.0 min. Mixing Water 0 %
Curing Period: Air Dried at Room Temperature

SAMPLE DIMENSIONS
Avg. Diam. 2.00"
Avg. Height 5.00"

SKETCH OF FAILURE



	Moulded	Start	End
Container No:			
Tare + Wet Sample - Gm			
Tare + Dry Sample - Gm			
Tare - Gm			
Wt. wet Sample - Gm			
Wt. Water - Gm			
Wt. Dry Sample - Gm	461.0		461.0
Wt. Asphalt - Gm			
Wt. Additive - Gm			
Volatiles - %			

Specific Gravity:
Volume of Sample: ______ cc. = ______ in^3
Volume of Soil Solids: ______ cc. Void
Volume of Voids: ______ cc. Ratio: ______
Degree of Saturation: ______ %
Density: ______ Dry: ______ pcf Wet ______ pcf
REMARKS:

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand | Additive: None | Amount: 0 %

Specific Gravity of Agg. 2.63 | Curing Period: Air Dried

Specific Gravity of AC. 1.00 | Type of Asphalt: SS-1 Emulsion

Specific Gravity of Add. 2.20 | Tested: J.A.K. | Date: 17-10-61

No.	Weight - Grams: Sample Dry	Sample Wet	AC	Add.	Water	Volume- cc.: Soil Solids	Voids	Voids: % Filled With AC	Add.	Water	% in Agg.	% in Total Mix	Density: Agg. pcf	Mix pcf	Failure Strain (%)	Unconf. Strength (psi)
2-1	405.0														0.5	9.34
2-2	404.0														0.5	7.59
2-3	404.5														0.8	8.08
AVG	404.5		8.0	-	-	150.8	104.2	7.7	-	-	40.9	37.8	96.8	98.7		8.34
3-1	416.5														1.2	3.43
3-2	415.0														0.8	3.53
3-3	415.0														1.0	3.44
AVG	415.5		12.1	-	-	153.4	101.6	11.9	-	-	39.8	35.2	98.4	101.4		3.47
4-1	429.0														1.0	3.14
4-2	430.5														1.2	3.24
4-3	430.5														1.2	3.03
AVG	430.0		16.5	-	-	157.2	97.8	16.9	-	-	38.3	31.7	100.9	104.9		3.14
5-1	444.0														1.4	4.42
5-2	445.5														1.6	4.51
5-3	450.5														1.6	4.83
AVG	446.7		21.2	-	-	161.8	93.2	22.8	-	-	36.6	28.3	103.8	109.0		4.59
6-1	448.5														1.2	4.62
6-2	452.0														1.6	4.62
6-3	452.0														1.2	4.84
AVG	450.8		25.5	-	-	161.8	93.2	27.4	-	-	36.6	26.5	103.8	109.9		4.69

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand | Additive: Lime | Amount: 1.0 %

Specific Gravity of Agg. 2.63 | Curing Period: Air Dried

Specific Gravity of AC. 1.00 | Type of Asphalt: SS-1 Emulsion

Specific Gravity of Add. 2.20 | Tested: J.A.K. | Date: 17-10-61

No.	Weight - Grams: Sample Dry	Weight - Grams: Sample Wet	Weight - Grams: AC	Weight - Grams: Add.	Weight - Grams: Water	Volume- cc.: Soil Solids	Volume- cc.: Voids	Voids: % Filled With AC	Voids: % Filled With Add.	Voids: % Filled With Water	Voids: % in Agg.	Voids: % in Total Mix	Density: Agg. pcf	Density: Mix pcf	Failure Strain (%)	Unconf. Strength (psi)
2-1	418.0														0.4	6.90
2-2	419.5														0.6	5.79
2-3	419.5														0.6	6.08
AVG	419.0		8.2	4.0	-	154.7	100.3	8.2	1.8	-	39.3	35.4	99.3	102.2		6.29
3-1	421.0														1.4	6.74
3-2	424.5														1.4	6.83
3-3	423.0														1.4	6.83
AVG	422.8		12.1	4.1	-	154.6	100.4	12.0	1.8	-	39.3	33.9	99.2	103.2		6.79
4-1	437.0														1.6	6.74
4-2	438.5														1.6	6.65
4-3	442.0														1.6	6.65
AVG	439.2		16.8	4.1	-	159.1	95.9	17.5	1.9	-	37.6	30.3	102.1	107.1		6.68
5-1	457.0														1.8	6.50
5-2	459.0														1.8	6.31
5-3	460.0														1.8	6.41
AVG	458.7		21.7	4.3	-	164.6	90.4	24.0	2.2	-	35.5	26.3	105.6	111.9		6.41
6-1	456.0														1.8	6.50
6-2	460.5														2.0	5.98
6-3	459.0														1.8	6.41
AVG	458.5		25.7	4.3	-	162.9	92.1	27.9	2.1	-	36.1	25.2	104.6	111.9		6.30

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand | Additive: Lime | Amount: 3.0 %

Specific Gravity of Agg. 2.63 | Curing Period: Air Dried

Specific Gravity of AC. 1.00 | Type of Asphalt: SS-1 Emulsion

Specific Gravity of Add. 2.20 | Tested: J.A.K. | Date: 17-10-61

No.	Weight - Grams					Volume- cc.		Voids					Density		Failure Strain (%)	Unconf. Strength (psi)
	Sample Dry	Sample Wet	AC	Add.	Water	Soil Solids	Voids	% Filled With AC	% Filled With Add.	% Filled With Water	% in Agg.	% in Total Mix	Agg. pcf	Mix pcf		
2-1	424.5														0.5	13.48
2-2	419.5														0.6	12.56
2-3	424.0														0.6	11.68
AVG	422.7		8.1	12.1	-	153.0	102.0	7.9	5.4	-	40.0	34.8	98.2	103.2		12.57
3-1	434.0														1.0	14.95
3-2	433.0														1.0	15.96
3-3	431.0														1.0	15.27
AVG	432.7		12.2	12.2	-	155.2	99.8	12.2	5.5	-	39.1	32.2	99.6	105.6		15.39
4-1	452.0														1.2	19.97
4-2	453.0														1.4	19.59
4-3	446.5														1.4	19.09
AVG	450.5		16.8	12.6	-	160.1	94.9	17.7	6.0	-	37.3	28.4	102.7	109.9		19.55
5-1	462.0														1.6	17.49
5-2	463.5														1.8	16.63
5-3	461.0														2.0	15.89
AVG	462.2		21.4	12.6	-	162.7	92.3	23.2	6.3	-	36.2	25.5	104.4	112.7		16.67
6-1	460.5														2.4	12.27
6-2	461.0														1.8	12.22
6-3	464.5														1.8	12.53
AVG	462.0		25.4	12.7	-	161.2	93.8	27.1	6.2	-	36.8	24.5	103.5	112.7		12.33

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand | Additive: None | Amount: 0 %
Specific Gravity of Agg. 2.63 | Curing Period: Freeze-Thaw
Specific Gravity of AC. 1.00 | Type of Asphalt: SS-1
Specific Gravity of Add. --- | Tested: J.A.K. | Date: 23-10-61

No.	Weight - Grams					Volume - cc.		Voids					Density		Failure Strain (%)	Unconf. Strength (psi)
								% Filled With			% in Agg.	% in Total Mix				
	Sample Dry	Sample Wet	AC	Add.	Water	Soil Solids	Voids	AC	Add.	Water			Agg. pcf	Mix pcf		
2-7	407.1														0.8	4.36
2-8	406.7														0.6	5.17
2-9	404.7														0.4	4.56
AVG	406.3		8.0	0	0	151.5	103.5	7.7	0	0	40.7	37.5	97.2	99.1		4.70
3-7	418.0														0.6	2.84
3-8	415.3														0.8	3.74
3-9	417.6														1.2	3.23
AVG	417.0		12.2	0	0	153.9	101.1	12.0	0	0	39.7	34.9	98.8	101.7		3.29
4-7	428.5														1.6	2.61
4-8	429.5														1.0	3.34
4-9	434.9														0.8	4.04
AVG	431.0		16.5	0	0	157.6	97.4	17.0	0	0	38.2	31.7	101.2	105.2		3.33
5-7	445.2														1.0	4.25
5-8	447.5														1.0	4.45
5-9	447.0														1.0	4.45
AVG	446.6		21.2	0	0	161.8	93.2	22.7	0	0	36.6	28.2	103.7	109.0		4.38
6-7	454.0														1.2	4.43
6-8	451.0														1.2	4.53
6-9	451.4														1.0	4.25
AVG	452.1		25.6	0	0	162.2	92.8	27.6	0	0	36.4	26.3	104.1	110.3		4.40

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand　Additive: Lime　Amount: 1.0 %
Specific Gravity of Agg. 2.63　Curing Period: Freeze-Thaw
Specific Gravity of AC. 1.00　Type of Asphalt: SS-1
Specific Gravity of Add. 2.20　Tested: J.A.K.　Date: 24-10-61

No.	Weight - Grams: Sample Dry	Weight - Grams: Sample Wet	Weight - Grams: AC	Weight - Grams: Add.	Weight - Grams: Water	Volume - cc.: Soil Solids	Volume - cc.: Voids	Voids: % Filled With AC	Voids: % Filled With Add.	Voids: % Filled With Water	Voids: % in Agg.	Voids: % in Total Mix	Density: Agg. pcf	Density: Mix pcf	Failure Strain (%)	Unconf. Strength (psi)
2-7	419.1														--	--
2-8	418.5														0.5	7.30
2-9	419.6														0.7	5.86
AVG	419.1		8.2	4.0	0	154.7	100.3	8.2	1.8	0	39.3	35.3	99.3	102.2		6.58
3-7	420.6														1.0	6.07
3-8	424.1														1.2	5.54
3-9	422.5														1.0	6.17
AVG	422.4		12.1	4.1	0	154.4	100.6	12.0	1.9	0	39.4	33.9	99.1	103.1		5.93
4-7	440.0														1.4	6.45
4-8	440.2														1.4	6.63
4-9	434.4														1.2	6.55
AVG	438.2		16.8	4.1	0	158.7	96.3	17.5	1.9	0	37.7	30.5	101.7	106.9		6.54
5-7	455.5														1.6	6.23
5-8	461.5														1.4	6.53
5-9	458.3														1.4	6.73
AVG	458.4		21.7	4.3	0	164.4	90.6	23.9	2.2	0	35.5	26.2	105.5	111.9		6.50
6-7	459.3														1.4	5.13
6-8	459.7														1.4	5.33
6-9	457.0														1.4	4.95
AVG	458.7		25.7	4.3	0	163.0	92.0	28.0	2.1	0	36.1	25.2	104.6	112.0		5.14

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand — Additive: Lime — Amount: 3.0 %
Specific Gravity of Agg. 2.63 — Curing Period: Freeze-Thaw
Specific Gravity of AC. 1.00 — Type of Asphalt: SS-1
Specific Gravity of Add. 2.20 — Tested: J.A.K. — Date: 24-10-61

No.	Weight - Grams: Sample Dry	Sample Wet	AC	Add.	Water	Volume- cc.: Soil Solids	Voids	Voids: % Filled With AC	Add.	Water	% in Agg.	% in Total Mix	Density: Agg. pcf	Mix pcf	Failure Strain (%)	Unconf. Strength (psi)
2-7	424.5														0.4	10.14
2-8	426.0														---	-----
2-9	424.5														0.4	7.91
AVG	425.0		8.1	12.1	0	154.0	101.0	8.0	5.4	0	39.6	34.3	98.8	103.7		9.02
3-7	434.1														1.0	21.74
3-8	433.0														1.0	22.75
3-9	434.5														0.8	23.36
AVG	433.9		12.3	12.3	0	155.7	99.3	12.4	5.6	0	38.9	31.9	99.9	105.9		22.62
4-7	448.2														1.8	26.94
4-8	446.7														1.6	28.84
4-9	446.5														1.8	28.35
AVG	447.1		16.8	12.5	0	158.8	96.2	17.5	5.9	0	37.7	28.9	102.0	109.1		28.04
5-7	460.0														2.2	23.76
5-8	463.0														2.2	24.16
5-9	464.3														2.2	20.97
AVG	462.4		21.4	12.9	0	162.7	92.3	23.2	6.3	0	36.2	25.5	104.4	112.8		22.96
6-7	464.2														2.0	20.27
6-8	461.9														2.0	20.07
6-9	467.7														2.0	21.47
AVG	464.6		25.6	12.9	0	162.0	93.0	27.6	6.3	0	36.5	24.1	103.9	113.4		20.60

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand   Additive: None   Amount: 0 %
Specific Gravity of Agg. 2.63   Curing Period: Water Immersion
Specific Gravity of AC. 1.00   Type of Asphalt: SS-1 Emulsion
Specific Gravity of Add. 2.20   Tested: J.A.K.   Date: 17-10-61

No.	Weight - Grams					Volume- cc.		Voids					Density		Failure Strain (%)	Unconf. Strength (psi)
								% Filled With			% in Agg.	% in Total Mix				
	Sample Dry	Sample Wet	AC	Add.	Water	Soil Solids	Voids	AC	Add.	Water			Agg. pcf	Mix pcf		
2-4		-													-	-
2-5		- -													-	-
2-6		-													-	-
AVG																
3-4	417.4	488.0													1.4	4.42
3-5	416.5	491.1													1.2	4.33
3-6	414.0	482.1													1.2	4.13
AVG	416.0	487.1	12.1	-	71.1	153.6	101.4	11.9	-	70.2	39.7	35.0	98.6	101.5		4.29
4-4	428.7	497.2													1.4	4.62
4-5	430.2	502.4													1.4	4.92
4-6	430.9	499.5													1.6	4.92
AVG	429.9	499.7	16.5	-	69.8	157.2	97.8	16.9	-	71.4	38.3	31.9	100.9	104.9		4.82
5-4	446.8	513.3													2.0	8.09
5-5	446.5	516.0													2.0	7.69
5-6	448.2	516.5													2.0	8.09
AVG	447.2	515.2	21.3	-	68.0	162.0	93.0	22.9	-	73.2	36.5	28.1	103.9	109.1		7.96
6-4	455.0	512.1													2.0	8.39
6-5	450.9	508.6													2.0	8.09
6-6	453.1	508.6													2.0	8.59
AVG	453.0	509.8	25.7	-	56.8	162.5	92.5	27.8	-	61.4	36.3	26.2	104.3	110.5		8.36

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand | Additive: Lime | Amount: 1.0 %

Specific Gravity of Agg. 2.63 | Curing Period: Water Immersion

Specific Gravity of AC. 1.00 | Type of Asphalt: SS-1 Emulsion

Specific Gravity of Add. 2.20 | Tested: J.A.K. | Date: 17-10-61

No.	Weight - Grams: Sample Dry	Sample Wet	AC	Add.	Water	Volume- cc.: Soil Solids	Voids	Voids: % Filled With AC	Add.	Water	% in Agg.	% in Total Mix	Density: Agg. pcf	Mix pcf	Failure Strain (%)	Unconf. Strength (psi)
2-4	418.1	459.3													0.8	8.49
2-5	419.1	458.6													0.8	7.98
2-6	418.6	462.0													0.8	7.98
AVG	418.6	460.0	8.2	4.0	41.4	154.5	100.5	8.2	1.8	41.2	39.4	35.5	99.2	102.1		8.15
3-4	422.1	474.4													1.4	14.07
3-5	422.8	477.7													1.4	13.56
3-6	424.0	475.7													1.4	13.16
AVG	423.0	475.6	12.2	4.1	52.6	154.6	100.4	12.1	1.9	52.4	39.4	33.9	99.3	103.2		13.60
4-4	441.5	500.3													2.0	16.77
4-5	441.7	498.0													2.4	16.62
4-6	440.5	498.2													2.0	15.17
AVG	441.2	498.8	16.8	4.1	57.6	159.8	95.2	17.7	2.0	60.6	37.3	30.0	102.6	107.6		16.19
5-4	457.9	510.5													2.4	18.12
5-5	456.1	509.0													2.4	17.82
5-6	457.1	508.7													2.8	17.52
AVG	457.0	509.4	21.6	4.3	52.4	163.9	91.1	23.7	2.2	57.4	35.7	26.5	105.2	111.5		17.82
6-4	456.7	508.0													2.4	16.13
6-5	454.1	500.0													2.4	14.43
6-6	459.7	502.9													2.4	16.82
AVG	456.8	503.6	25.6	4.3	46.8	164.2	92.8	27.6	2.2	50.5	36.2	25.6	104.2	111.5		15.79

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand Additive: Lime Amount: 3.0 %

Specific Gravity of Agg. 2.63 Curing Period: Water Immersion

Specific Gravity of AC. 1.00 Type of Asphalt: SS-1

Specific Gravity of Add. 2.20 Tested: J.A.K. Date: 6-11-61

No.	Weight - Grams					Volume- cc.		Voids					Density		Failure Strain (%)	Unconf. Strength (psi)
								% Filled With			% in Agg.	% in Total Mix				
	Sample Dry	Sample Wet	AC	Add.	Water	Soil Solids	Voids	AC	Add.	Water			Agg. pcf	Mix pcf		
2-4	425.5	468.5													0.6	17.75
2-5	421.4	467.6													0.8	14.45
2-6	424.9	466.0													0.6	13.89
AVG	423.9	467.4	8.1	12.1	43.5	153.5	101.5	8.0	4.5	42.9	39.9	34.8	98.5	103.5		15.36
3-4	428.5	471.8													1.2	27.52
3-5	434.1	478.9													1.4	26.82
3-6	432.6	475.1													1.4	27.63
AVG	431.7	475.3	12.2	12.2	43.6	154.9	100.1	12.2	4.6	42.5	39.3	32.7	99.4	105.3		27.32
4-4	447.5	494.7													1.9	34.55
4-5	450.0	492.4													1.6	35.47
4-6	447.2	493.5													1.8	35.26
AVG	448.2	493.5	16.8	12.6	45.3	159.2	95.8	17.5	5.0	47.3	37.6	29.1	102.2	109.4		35.09
5-4	459.9	500.5													2.8	28.68
5-5	459.0	501.6													2.4	26.08
5-6	463.1	504.1													2.4	27.67
AVG	460.7	502.1	21.3	12.8	41.4	162.2	92.8	22.9	5.3	44.6	36.4	26.1	104.1	112.4		27.48
6-4	463.4	504.0													2.4	22.89
6-5	464.4	501.9													2.4	24.68
6-6	465.2	504.5													2.4	24.19
AVG	464.3	503.5	25.6	12.9	39.2	161.9	93.1	27.5	5.4	42.2	36.5	24.5	103.9	113.3		23.92

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand   Additive: None   Amount: 0 %

Specific Gravity of Agg. 2.63   Curing Period: Air Dried

Specific Gravity of AC. 1.00   Type of Asphalt: 150-200 Pen.

Specific Gravity of Add. 2.20   Tested: J.A.K.   Date: 13-11-61

No.	Weight - Grams: Sample Dry	Sample Wet	AC	Add.	Water	Volume- cc.: Soil Solids	Voids	Voids: % Filled With AC	Add.	Water	% in Agg.	% in Total Mix	Density: Agg. pcf	Mix pcf	Failure Strain (%)	Unconf. Strength (psi)
2-7	412.0														0.8	2.93
2-8	414.0														1.0	2.63
2-9	412.5														1.0	3.03
AVG	412.8		8.2	-	-	153.8	101.2	8.1	-	-	39.7	36.5	98.7	100.7		2.86
3-7	427.0														1.2	4.33
3-8	423.0														1.4	4.32
3-9	426.5														1.2	5.63
AVG	425.5		12.4	-	-	157.0	98.0	12.7	-	-	38.4	33.4	100.8	103.8		4.76
4-7	428.0														1.6	3.02
4-8	428.0														1.0	3.13
4-9	428.5														1.6	4.32
AVG	428.1		16.5	-	-	156.5	98.5	16.9	-	-	38.6	32.0	100.4	104.4		3.49
5-7	430.5														1.6	4.02
5-8	431.0														1.2	2.82
5-9	427.5														1.2	4.23
AVG	429.7		20.5	-	-	155.6	99.4	20.6	-	-	38.9	30.9	99.8	104.8		3.69
6-7	433.5														1.8	4.11
6-8	431.0														1.4	4.02
6-9	435.0														2.0	4.49
AVG	433.2		24.5	-	-	155.5	99.5	24.6	-	-	39.0	29.4	99.8	105.7		4.21

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand — Additive: Lime — Amount: 1.0 %
Specific Gravity of Agg. 2.63 — Curing Period: Air Dried
Specific Gravity of AC. 1.00 — Type of Asphalt: 150-200 Pen.
Specific Gravity of Add. 2.20 — Tested: J.A.K. — Date: 13-11-61

No.	Weight - Grams					Volume- cc.		Voids					Density		Failure Strain (%)	Unconf. Strength (psi)
								% Filled With			% in Agg.	% in Total Mix				
	Sample Dry	Sample Wet	AC	Add.	Water	Soil Solids	Voids	AC	Add.	Water			Agg. pcf	Mix pcf		
2-7	420.0														1.4	5.73
2-8	416.0														1.2	5.84
2-9	417.0														1.2	5.84
AVG	417.7		8.2	4.0	-	154.2	100.8	8.2	1.8	-	39.5	35.3	99.0	101.9		5.80
3-7	430.0														1.4	4.72
3-8	432.0														1.6	4.02
3-9	431.5														1.4	4.82
AVG	431.2		12.4	4.2	-	157.6	97.4	12.7	2.0	-	38.2	32.4	101.2	105.2		4.52
4-7	432.5														1.2	4.03
4-8	431.0														1.8	3.51
4-9	433.5														1.4	4.02
AVG	432.3		16.5	4.1	-	156.6	98.4	16.8	1.9	-	38.6	31.3	100.4	105.5		3.85
5-7	429.0														1.4	2.36
5-8	429.0														1.2	2.42
5-9	430.5														1.0	2.63
AVG	429.8		20.3	4.1		154.2	100.8	20.2	1.9	-	39.5	30.9	98.9	104.9		2.47
6-7	442.5														1.8	5.23
6-8	440.5														1.6	4.52
6-9	-														-	-
AVG	441.5		24.8	4.1	-	156.9	98.1	25.3	1.9	-	38.5	27.8	100.6	107.7		4.88

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand — Additive: Lime — Amount: 3.0 %

Specific Gravity of Agg. 2.63 — Curing Period: Air Dried

Specific Gravity of AC. 1.00 — Type of Asphalt: 150-200 Pen.

Specific Gravity of Add. 2.20 — Tested: J.A.K. — Date: 13-11-61

No.	Weight - Grams: Sample Dry	Sample Wet	AC	Add.	Water	Volume- cc.: Soil Solids	Voids	Voids: % Filled With AC	Add.	Water	% in Agg.	% in Total Mix	Density: Agg. pcf	Mix pcf	Failure Strain (%)	Unconf. Strength (psi)
2-7	419.5														1.2	6.35
2-8	421.0														1.2	7.26
2-9	422.0														1.6	7.13
AVG	420.8		8.0	12.0	-	152.4	102.6	7.8	5.3	-	40.1	35.0	97.8	102.7		6.91
3-7	436.0														2.0	8.99
3-8	436.5														1.8	9.82
3-9	437.0														2.0	9.69
AVG	436.5		12.3	12.3	-	156.7	98.3	12.5	5.7	-	38.5	31.5	100.5	106.5		9.50
4-7	439.0														2.0	8.79
4-8	437.0														2.2	9.98
4-9	439.0														2.0	10.68
AVG	438.3		16.5	12.3	-	155.7	99.3	16.6	5.6	-	38.9	30.2	99.9	106.9		9.82
5-7	434.5														2.0	4.99
5-8	433.5														2.0	4.89
5-9	432.0														2.0	5.49
AVG	433.3		20.0	12.0	-	152.6	102.4	19.5	5.3	-	40.1	30.6	97.8	105.7		5.12
6-7	457.5														3.6	12.78
6-8	461.0														2.8	13.96
6-9	-														-	-
AVG	459.3		25.3	12.7	-	160.2	94.8	26.7	6.1	-	37.1	25.0	102.8	112.0		13.36

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand   Additive: None   Amount: 0 %

Specific Gravity of Agg. 2.63   Curing Period: Freeze - Thaw

Specific Gravity of AC. 1.00   Type of Asphalt: 150-200 Pen.

Specific Gravity of Add. 2.20   Tested: J.A.K.   Date: 15-11-61

No.	Weight - Grams					Volume - cc.		Voids					Density		Failure Strain (%)	Unconf. Strength (psi)
								% Filled With			% in Agg.	% in Total Mix				
	Sample Dry	Sample Wet	AC	Add.	Water	Soil Solids	Voids	AC	Add.	Water			Agg. pcf	Mix pcf		
2-1	408.0														1.0	2.32
2-2	407.0														1.2	2.42
2-3	410.0														1.0	2.53
AVG	408.3		8.1	-	-	152.2	102.8	7.9	-	-	40.3	37.9	97.6	99.6		2.42
3-1	423.0														1.4	4.52
3-2	425.0														1.4	4.52
3-3	427.5														1.4	4.02
AVG	425.2		12.4	-	-	156.9	98.1	12.7	-	-	38.5	32.8	100.8	103.7		4.35
4-1	430.0														1.0	3.33
4-2	430.5														1.0	2.93
4-3	432.5														1.0	3.03
AVG	431.0		16.5	-	-	157.6	97.4	17.0	-	-	38.2	31.7	101.2	105.2		3.09
5-1	427.5														1.2	2.67
5-2	431.0														1.0	2.63
5-3	430.0														1.2	2.52
AVG	429.5		20.5	-	-	155.5	99.5	20.6	-	-	39.0	31.2	99.8	104.8		2.61
6-1	436.5														1.0	2.83
6-2	430.0														1.6	2.46
6.3	431.0														1.0	2.73
AVG	432.5		24.5	-	-	155.1	99.9	24.5	-	-	39.2	29.6	99.6	105.6		2.67

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand | Additive: Lime | Amount: 1.0 %

Specific Gravity of Agg. 2.63 | Curing Period: Freeze-Thaw

Specific Gravity of AC. 1.00 | Type of Asphalt: 150-200 Pen.

Specific Gravity of Add. 2.20 | Tested: J.A.K. | Date: 15-11-61

No.	Weight - Grams					Volume- cc.		Voids					Density		Failure Strain (%)	Unconf. Strength (psi)
								% Filled With			% in Agg.	% in Total Mix				
	Sample Dry	Sample Wet	AC	Add.	Water	Soil Solids	Voids	AC	Add.	Water			Agg. pcf	Mix pcf		
2-1	-														-	-
2-2	415.0														1.0	3.84
2-3	417.0														1.0	5.86
AVG	416.0		8.1	4.0	-	153.6	101.4	8.0	1.8	-	39.8	35.9	98.6	101.5		4.85
3-1	-														-	-
3-2	429.0														1.2	4.73
3-3	431.0														1.2	5.44
AVG	430.0		12.4	4.2	-	157.2	97.8	12.7	2.0	-	38.4	32.7	100.9	104.9		5.09
4-1	-														-	-
4-2	428.0														1.4	3.72
4-3	434.0														1.6	4.93
AVG	431.0		16.4	4.1	-	156.1	98.9	16.8	1.9	-	38.8	31.5	100.2	105.2		4.33
5-1	-														-	-
5-2	428.0														1.2	2.72
5-3	433.0														1.4	3.42
AVG	430.5		20.3	4.1	-	154.4	100.6	20.2	1.8	-	39.5	30.8	99.1	105.1		3.07
6-1	-														-	-
6-2	437.0														1.8	4.41
6-3	438.5														2.0	4.49
AVG	437.8		24.6	4.1	-	155.5	99.5	24.8	1.9	-	39.0	28.5	99.8	106.8		4.45

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand | Additive: Lime | Amount: 3.0 %
Specific Gravity of Agg. 2.63 | Curing Period: Freeze - Thaw
Specific Gravity of AC. 1.00 | Type of Asphalt: 150-200 Pen.
Specific Gravity of Add. 2.20 | Tested: J.A.K. | Date: 15-11-61

No.	Weight - Grams					Volume - cc.		Voids					Density		Failure Strain (%)	Unconf. Strength (psi)
	Sample Dry	Sample Wet	AC	Add.	Water	Soil Solids	Voids	% Filled With AC	% Filled With Add.	% Filled With Water	% in Agg.	% in Total Mix	Agg. pcf	Mix pcf		
2-1	-														-	-
2-2	413.5														1.6	8.24
2-3	414.0														1.6	8.34
AVG	413.8		7.9	11.8	-	149.8	105.2	7.5	5.1	-	41.4	36.3	96.1	101.0		8.29
3-1	-														-	-
3-2	434.0														1.8	10.02
3-3	434.0														1.8	10.72
AVG	434.0		12.3	12.3	-	155.7	99.3	12.4	5.6	-	39.0	31.9	99.9	105.9		10.37
4-1	-														-	-
4-2	431.0														2.4	9.56
4-3	438.5														2.0	9.98
AVG	435.2		16.3	12.2	-	154.6	100.4	16.2	5.5	-	39.4	30.9	99.2	106.1		9.77
5-1	-														-	-
5-2	434.0														2.4	7.27
5-3	433.0														2.8	6.76
AVG	433.5		20.1	12.1	-	152.6	102.4	19.7	5.4	-	40.2	30.3	97.8	105.8		7.02
6-1	-														-	-
6-2	461.0														2.4	6.77
6-3	456.5														2.4	6.37
AVG	458.8		25.2	12.7	-	156.3	98.7	25.5	5.8	-	38.7	26.4	102.7	112.0		6.57

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand Additive: None Amount: 0 %
Specific Gravity of Agg. 2.63 Curing Period: Water Immersion
Specific Gravity of AC. 1.00 Type of Asphalt: 150-200 Pen.
Specific Gravity of Add. 2.20 Tested: J.A.K. Date: 8-11-61

No.	Weight - Grams: Sample Dry	Sample Wet	AC	Add.	Water	Volume- cc.: Soil Solids	Voids	Voids: % Filled With: AC	Add.	Water	% in Agg.	% in Total Mix	Density: Agg. pcf	Mix pcf	Failure Strain (%)	Unconf. Strength (psi)
2-4	407.8	460.0													1.4	4.52
2-5	410.1	461.3													1.6	4.92
2-6	408.7	458.4													1.2	4.13
AVG	408.9	459.9	8.1	-	51.0	152.4	102.6	7.9	-	49.7	40.2	37.1	97.8	99.8		4.52
3-4	429.5	479.7													2.0	10.05
3-5	423.8	474.7													2.0	7.59
3-6	427.7	478.8													2.0	8.09
AVG	427.0	477.7	12.4	-	50.7	157.6	97.4	12.7	-	52.1	38.2	33.3	101.1	104,2		8.58
4-4	430.7	475.0													2.4	6.57
4-5	429.6	472.9													2.4	6.17
4-6	427.3	472.1													2.8	6.86
AVG	429.2	473.3	16.5	-	44.1	156.9	98.1	16.8	-	44.9	38.5	32.0	100.7	104.7		6.53
5-4	428.3	471.0													2.8	7.14
5-5	430.0	473.2													2.8	6.44
5-6	430.7	472.5													2.4	7.05
AVG	429.7	472.2	20.5	-	42.5	155.6	99.4	20.6	-	42.8	38.9	30.9	99.8	104.8		6.88
6-4	433.6	470.4													2.8	6.54
6-5	435.0	473.4													2.8	6.64
6-6	436.2	472.2													2.4	7.37
AVG	434.9	472.0	24.6	-	37.1	156.0	99.0	24.9	-	37.5	38.9	29.2	100.1	106.1		6.85

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand
Additive: Lime Amount: 1.0 %
Specific Gravity of Agg. 2.63
Curing Period: Water Immersion
Specific Gravity of AC. 1.00
Type of Asphalt: 150-200 Pen.
Specific Gravity of Add. 2.20
Tested: J.A.K. Date: 17-11-61

No.	Weight - Grams					Volume- cc.		Voids					Density		Failure Strain (%)	Unconf. Strength (psi)
								% Filled With			% in Agg.	% in Total Mix				
	Sample Dry	Sample Wet	AC	Add.	Water	Soil Solids	Voids	AC	Add.	Water			Agg. pcf	Mix pcf		
2-4	419.6	461.5													1.6	9.04
2-5	418.1	460.6													1.6	8.94
2-6	415.6	458.7													2.0	8.99
AVG	417.8	460.3	8.2	4.0	42.5	154.2	100.8	8.1	1.8	42.2	39.5	35.6	99.0	101.9		8.99
3-4	431.1	475.0													2.0	10.08
3-5	431.3	473.4													2.0	9.59
3-6	430.0	474.5													2.0	9.69
AVG	430.8	474.3	12.4	4.2	43.5	157.4	97.6	12.7	2.0	44.6	38.3	32.7	101.0	105.2		9.79
4-4	430.0	475.5													2.4	8.96
4-5	433.1	475.1													1.6	9.24
4-6	430.8	474.5													2.0	9.49
AVG	431.3	475.0	16.4	4.1	43.7	156.3	98.7	16.6	1.9	44.3	38.7	31.6	100.3	105.3		9.23
5-4	427.6	468.2													2.0	7.49
5-5	426.1	470.0													2.0	7.49
5-6	424.8	467.0													2.4	7.17
AVG	426.2	468.4	20.0	4.0	42.2	152.9	102,1	19.5	1.8	41.2	40.1	31.7	98.1	103.9		7.38
6-4	436.1	479.0													2.8	7.74
6-5	437.3	481.7													2.8	8.53
6-6	439.5	482.7													2.8	12.41
AVG	437.6	481.1	24.6	4.1	43.5	155.5	99.5	24.8	1.9	43.8	39.0	28.5	99.8	106.8		9.56

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

UNCONFINED COMPRESSION TESTS
on
SOIL-ASPHALT MIXTURES

Project: Marchand | Additive: Lime | Amount: 3.0 %

Specific Gravity of Agg. 2.63 | Curing Period: Water Immersion

Specific Gravity of AC. 1.00 | Type of Asphalt: 150-200 Pen.

Specific Gravity of Add. 2.20 | Tested: J.A.K. | Date: 8-11-61

No.	Weight - Grams					Volume- cc.		Voids					Density		Failure Strain (%)	Unconf. Strength (psi)
								% Filled With			% in Agg.	% in Total Mix				
	Sample Dry	Sample Wet	AC	Add.	Water	Soil Solids	Voids	AC	Add.	Water			Agg. pcf	Mix pcf		
2-4	419.0	456.7													1.6	10.05
2-5	418.4	454.3													1.6	9.95
2-6	420.4	457.0													1.6	9.95
AVG	419.3	456.0	8.0	12.0	36.7	151.9	103.1	7.8	5.3	35.6	40.4	35.3	97.5	102.3		9.98
3-4	433.7	469.6													2.0	17.77
3-5	435.5	470.6													2.4	18.12
3-6	434.9	469.5													2.4	17.62
AVG	434.7	469.9	12.3	12.3	35.2	155.9	99.1	12.4	5.7	35.5	38.9	31.9	100.0	106.0		17.84
4-4	436.5	474.0													2.8	17.47
4-5	435.5	472.6													2.4	17.17
4-6	433.5	471.4													2.4	17.02
AVG	435.2	472.7	16.3	12.2	37.5	154.6	100.4	16.2	5.6	37.3	39.4	30.8	99.2	106.1		17.22
5-4	434.4	473.8													2.8	14.98
5-5	435.5	473.5													2.8	13.60
5-6	439.0	476.8													2.8	14.58
AVG	436.3	474.7	20.1	12.1	38.4	153.6	101.4	19.8	5.4	37.9	39.8	29.9	98.6	106.6		14.39
6-4	457.3	491.2													2.8	14.98
6-5	456.8	493.4													2.8	14.78
6-6	455.3	489.9													2.8	15.28
AVG	456.5	491.5	25.1	12.6	35.0	159.3	95.7	26.2	6.0	36.6	37.5	25.5	102.2	111.4		15.01

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section
SAND - ASPHALT STABILIZATION

Project: Marchand
Date Started: July 24, 1961
Date Completed: Aug. 10, 1961

Test: Freeze - Thaw
Type of Asphalt: SS-1 Emulsion
Type of Additive: None

Date	Wt.	Temp.	2-0-7	2-0-8	2-0-9	3-0-7	3-0-8	3-0-9	4-0-7	4-0-8	4-0-9	5-0-7	5-0-8	5-0-9	6-0-7	6-0-8	6-0-9
7- 24	Air	-8°C	407.1	406.7	404.7	418.0	415.3	417.6	428.5	429.5	434.9	445.2	447.5	447.0	454.0	451.0	451.4
24	Water		152.9	152.0	151.1	162.6	160.3	162.2	173.6	175.5	179.4	191.0	193.6	193.0	199.2	197.0	196.1
25	Air	-8°C	408.4	408.5	405.6	418.8	416.2	419.1	429.6	430.8	436.3	445.8	449.3	448.6	455.5	452.1	452.0
26	Air	-8°C	405.5	403.3	401.2	419.0	416.3	418.9	429.9	431.1	436.3	447.0	450.0	449.6	456.3	453.0	452.5
27	Air	-8°C	407.7	400.0	398.8	419.3	416.1	418.7	429.7	429.6	436.3	447.1	450.0	449.3	456.4	452.6	452.4
28	Air	-6°C	393.1	396.0	388.2	417.6	413.6	416.1	429.2	429.5	436.1	446.6	449.6	449.7	455.4	453.0	453.3
29	Air	-9°C	391.8	391.6	385.2	418.9	414.7	417.7	429.1	428.9	435.2	447.4	450.4	449.7	456.7	453.2	453.0
31	Air	-8°C	381.2	381.0	372.4	418.0	411.0	416.6	429.7	428.3	435.4	446.8	449.9	449.3	455.7	453.0	452.4
31	Water		145.4	144.4	141.9	162.8	159.9	161.6	174.0	174.7	180.0	192.7	195.2	194.5	199.7	198.3	197.5
8- 1	Air	-8°C	377.0	377.5	367.2	417.8	413.8	417.0	429.3	429.0	436.5	446.8	449.9	449.4	456.0	453.3	452.9
2	Air	-8°C	369.2	371.0	358.7	417.3	413.6	416.8	428.8	428.3	435.6	447.0	450.0	449.5	456.0	453.0	452.9
3	Air	-9°C	361.2	368.1	354.0	417.0	413.7	416.5	428.4	427.8	434.8	446.3	449.9	449.1	456.1	453.2	453.1
4	Air	-8°C	355.3	361.8	347.5	416.3	412.8	416.0	428.3	427.9	434.5	446.3	449.3	448.9	456.5	452.7	452.8
5	Air	-8°C	350.5	357.3	346.1	416.8	413.5	415.1	428.0	425.2	434.9	446.8	449.6	448.9	456.1	453.2	452.6
8	Air	-8°C	339.7	350.3	332.6	415.8	413.0	415.6	427.1	428.0	435.3	446.7	449.4	449.0	455.9	452.7	452.4
9	Air	-7°C	332.6	348.1	329.4	415.2	412.7	415.3	426.6	427.9	435.0	446.3	449.1	448.7	445.6	452.4	452.3
9	Water		126.4	132.7	125.9	162.4	159.7	161.6	174.8	174.4	180.6	193.6	195.5	195.1	200.0	197.7	197.1

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section
SAND - ASPHALT STABILIZATION

Project: Marchand
Date Started: Aug. 9, 1961
Date Completed: Aug. 30, 1961

Test: Freeze - Thaw
Type of Asphalt: SS-1 Emuslion
Type of Additive: Lime

Date	Wt.	Temp.	2-1-7	2-1-8	2-1-9	3-1-7	3-1-8	3-1-9	4-1-7	4-1-8	4-1-9	5-1-7	5-1-8	5-1-9	6-1-7	6-1-8	6-1-9
8- 9	Air		419.1	418.5	419.6	420.6	424.1	422.5	440.0	440.2	434.4	455.5	461.5	458.3	459.3	459.7	457.0
9	Water		164.5	164.3	165.8	167.8	169.1	169.8	185.6	185.5	181.1	202.6	206.4	204.2	204.4	205.2	204.0
10	Air	-8°C	419.9	420.0	421.4	422.4	425.4	423.8	441.3	441.3	435.7	456.7	461.8	459.6	460.0	460.0	458.8
11	Air	-8°C	417.9	418.9	420.0	421.6	425.0	423.5	440.9	440.9	435.0	456.3	461.9	458.5	459.8	459.8	457.9
12	Air	-5°C	419.2	418.0	418.9	422.5	425.3	423.9	441.7	441.6	435.6	456.9	462.3	459.7	460.7	460.4	458.7
13	Air	-5°C	417.7	417.0	418.7	423.0	425.7	424.7	442.6	442.3	437.0	457.0	463.0	459.7	460.8	460.8	458.9
15	Air	- 7°C	417.2	415.6	417.3	422.7	425.1	424.1	441.8	441.8	436.3	457.6	462.5	459.8	460.6	460.6	459.3
17	Air	-8°C	418.0	415.5	417.0	422.7	425.1	423.9	442.1	441.4	436.3	457.2	462.8	459.7	461.5	460.3	459.1
17	Water		165.4	163.8	165.8	168.5	170.3	170.9	187.1	186.6	182.5	204.0	208.0	205.3	206.9	206.6	205.4
18	Air	-7°C	414.9	413.5	409.2	422.5	425.1	424.5	441.8	441.8	435.6	458.1	463.1	460.0	460.8	461.1	459.3
22	Air	- 8°C	414.2	410.7	408.1	422.2	425.0	423.7	441.7	441.6	435.7	457.1	462.9	459.6	460.3	460.5	458.4
23	Air	-6°C	413.5	410.4	407.1	422.1	424.9	424.1	441.8	441.6	435.4	456.6	463.1	459.7	460.5	460.6	459.0
24	Air	-7°C	412.5	409.7	406.5	422.6	425.5	424.0	442.1	441.9	435.7	457.1	463.1	459.7	460.4	460.9	459.2
25	Air	-8°C	Broke	409.0	407.0	422.3	425.7	424.3	441.7	441.4	435.5	457.5	463.2	460.0	460.4	460.4	459.3
26	Air	-8°C		408.8	406.9	422.1	425.6	424.1	441.5	441.1	435.4	457.6	463.0	459.8	460.3	460.1	459.2
29	Air	-8°C		408.9	406.3	422.7	425.8	424.6	442.1	441.6	436.0	457.0	462.9	460.0	460.8	460.7	459.3
29	Water			161.3	161.6	168.5	170.4	170.8	187.0	187.0	182.2	203.9	207.9	205.5	206.5	206.5	205.5

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section
SAND - ASPHALT STABILIZATION

Project: Marchand
Date Started: Aug. 29, 1961
Date Completed: Sept. 14, 1961

Test: Freeze - Thaw
Type of Asphalt: SS-1 Emulsion
Type of Additive: Lime

Date	Wt.	Temp.	2-3-7	2-3-8	2-3-9	3-3-7	3-3-8	3-3-9	4-3-7	4-3-8	4-3-9	5-3-7	5-3-8	5-3-9	6-3-7	6-3-8	6-3-9
8- 29	Air	-	424.5	426.0	424.5	434.1	433.0	434.5	448.2	446.7	446.5	460.0	463.0	464.3	464.2	461.9	467.7
29	Water		168.8	170.8	169.8	180.0	179.3	180.0	193.5	192.5	191.8	205.9	207.8	209.0	210.3	209.2	213.3
30	Air	-8°C	426.2	427.3	425.8	435.5	433.4	435.3	448.9	447.6	447.2	460.9	463.2	465.8	464.5	462.6	468.5
31	Air	-8°C	426.4	427.7	426.8	436.9	435.0	437.2	450.7	448.3	448.3	461.9	464.0	467.0	466.1	463.5	470.0
9- 1	Air	-8°C	425.3	Broke	424.6	435.8	434.0	436.4	449.3	447.8	447.8	460.9	463.3	466.1	465.0	462.9	469.4
5	Air	-8°C	426.5		425.2	434.9	433.1	436.6	449.6	447.2	448.3	460.0	462.5	466.3	465.3	462.6	469.2
6	Air	-8°C	427.0		424.5	435.5	433.5	436.6	449.2	447.1	447.7	460.6	463.1	466.9	465.7	462.8	469.6
7	Air	-6°C	426.5		423.3	435.5	434.5	436.2	450.0	447.6	447.9	461.2	463.6	467.3	466.2	463.5	470.0
7	Water		172.4		171.1	180.4	179.2	181.8	189.7	192.8	192.5	206.3	207.8	210.0	211.6	209.5	213.9
8	Air	-6°C	426.6		423.1	436.6	435.0	438.0	451.7	448.5	448.9	462.0	464.3	467.5	466.3	464.0	470.4
9	Air	-8°C	426.5		423.0	436.4	434.7	438.1	451.5	448.4	448.3	461.6	464.0	467.1	466.1	463.8	470.1
10	Air	-8°C	426.1		422.8	436.1	437.5	438.2	451.2	448.1	447.8	461.3	463.9	466.8	465.7	463.7	470.0
11	Air	-8°C	426.3		420.9	436.2	434.5	437.7	450.0	448.2	448.9	461.3	463.6	466.9	466.3	463.5	470.3
12	Air	-7°C	427.0		421.4	436.8	434.9	437.5	450.4	448.1	448.1	461.8	463.8	467.0	466.0	464.6	470.7
13	Air	-6°C	425.8		420.6	436.0	434.3	437.7	450.0	448.0	448.0	461.2	463.6	467.5	465.8	463.3	469.6
14	Air	-7°C	425.0		420.5	436.2	434.4	437.6	450.0	448.5	448.4	461.7	464.5	467.7	466.4	464.4	470.0
14	Water		175.8		172.0	180.7	180.0	182.3	194.8	193.0	193.3	208.5	208.0	210.0	211.4	209.0	214.4

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section
SAND - ASPHALT STABILIZATION

Project: Marchand
Date Started: Sept. 18, 1961
Date Completed: Oct. 1, 1961

Test: Freeze - Thaw
Type of Asphalt: 150-200 Pen.
Type of Additive: None

Date	Wt.	Temp.	2-0-1	2-0-2	2-0-3	3-0-1	3-0-2	3-0-3	4-0-1	4-0-2	4-0-3	5-0-1	5-0-2	5-0-3	6-0-1	6-0-2	6-0-3
9- 18	Air	-	410.0	410.0	412.2	423.9	426.8	428.2	430.3	431.1	432.3	427.9	431.2	430.0	437.4	430.7	431.2
18	Water		154.4	154.3	157.3	167.9	170.3	170.8	175.9	175.1	177.2	173.4	176.0	175.5	181.7	176.0	177.4
19	Air	-8°C	410.3	410.3	413.0	424.0	426.5	428.9	430.7	431.5	433.4	429.1	431.5	430.3	437.3	431.1	431.6
20	Air	-8°C	410.3	410.1	413.7	423.8	427.7	429.3	431.5	431.8	434.1	429.2	431.7	431.1	438.8	431.3	432.7
21	Air	-8°C	410.4	410.4	413.4	424.8	427.1	429.1	431.7	432.6	434.5	429.1	432.4	431.2	437.9	431.9	432.8
22	Air	-5°C	410.1	410.3	412.9	424.5	427.3	428.3	431.2	432.0	433.5	429.3	432.3	430.7	438.7	432.2	433.0
23	Air	-8°C	410.2	410.4	413.0	424.7	427.2	429.2	431.8	432.1	433.8	429.2	432.5	431.3	438.8	432.7	433.3
24	Air	-8°C	410.3	410.3	412.9	424.9	427.1	429.1	432.0	432.3	434.3	429.0	432.7	431.6	438.9	433.0	433.6
24	Water		154.7	154.3	157.7	168.4	170.7	171.7	176.6	174.6	177.1	173.8	176.6	175.9	183.6	177.6	178.2
25	Air	-8°C	410.1	410.0	412.7	424.5	427.0	428.7	431.9	431.9	433.8	428.7	432.1	430.6	438.0	431.7	432.7
26	Air	-8°C	410.0	410.0	412.5	424.5	427.8	429.0	431.7	431.7	433.8	429.0	432.5	430.8	438.7	432.4	433.2
27	Air	-7°C	409.5	409.9	411.3	424.1	426.4	428.7	431.3	431.3	433.3	428.5	431.9	430.7	437.7	431.3	432.4
28	Air	-7°C	410.0	410.0	412.5	424.5	427.6	429.7	431.7	432.2	433.8	429.2	432.1	430.9	438.8	432.0	433.5
29	Air	-7°C	409.7	410.0	412.3	424.4	427.3	429.1	431.9	432.0	434.1	428.9	432.5	431.1	438.9	431.9	433.2
31	Air	-8°C	410.1	410.2	412.5	424.3	427.4	429.3	432.1	432.2	434.5	429.6	432.9	431.2	439.0	432.1	433.0
10-1	Air	-7°C	410.3	410.0	411.1	424.9	427.9	429.4	432.1	432.2	434.1	430.0	432.7	431.5	438.2	431.6	433.2
1	Water		154.9	154.2	156.6	168.4	171.0	172.1	177.1	175.3	178.2	174.7	176.8	176.5	183.7	177.9	178.5

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section
SAND - ASPHALT STABILIZATION

Project: Marchand
Date Started: Oct. 20, 1961
Date Completed: Nov. 3, 1961

Test: Freeze - Thaw
Type of Asphalt: 150-200 Pen.
Type of Additive: Lime

Date	Wt.	Temp.		2-1-2	2-1-3		3-1-2	3-1-3		4-1-2	4-1-3		5-1-2	5-1-3		6-1-2	6-1-3
10-20	Air			415.2	417.1		428.8	430.0		427.5	428.9		427.9	428.5		437.2	438.1
20	Water			160.0	161.6		172.9	173.4		173.0	173.7		172.6	173.2		181.9	181.1
21	Air	$-7^{\circ}C$		415.5	418.0		429.0	430.9		427.9	429.2		428.0	429.0		437.5	439.3
22	Air	$-7^{\circ}C$		415.8	418.1		429.5	431.0		428.3	430.0		428.5	429.3		438.2	440.0
23	Air	$-8^{\circ}C$		416.1	417.8		430.0	431.1		429.8	430.0		429.0	428.7		438.9	438.7
24	Air	$-8^{\circ}C$		416.3	418.0		430.2	430.9		430.3	430.3		430.2	429.2		438.7	439.1
25	Air	$-8^{\circ}C$		416.0	418.0		430.0	431.0		429.3	429.5		428.7	428.4		438.1	438.6
26	Air	$-8^{\circ}C$		416.3	418.2		430.3	431.2		430.2	430.0		429.3	429.0		439.2	439.8
26	Water			160.0	161.3		173.3	174.5		174.8	174.3		173.0	174.1		183.4	182.7
27	Air	$-7^{\circ}C$		416.0	418.0		430.0	431.1		430.1	429.8		429.4	429.1		439.4	439.7
28	Air	$-8^{\circ}C$		416.2	418.1		429.7	430.8		430.0	429.6		429.7	429.4		439.1	439.5
29	Air	$-8^{\circ}C$		416.1	418.6		429.5	431.0		430.2	430.7		429.9	429.5		439.3	440.3
30	Air	$-8^{\circ}C$		416.4	419.1		431.1	431.6		430.3	430.1		429.5	429.5		439.2	439.4
31	Air	$-7^{\circ}C$		416.5	417.3		431.2	431.0		429.1	430.0		429.2	429.4		438.6	440.4
11-1	Air	$-8^{\circ}C$		416.6	417.4		430.7	430.5		429.7	429.2		429.2	429.1		438.9	438.9
2	Air	$-7^{\circ}C$		415.5	417.7		429.8	430.9		429.7	430.7		428.7	429.1		438.3	439.0
2	Water			160.2	161.8		172.5	174.6		174.7	176.1		173.4	174.4		183.0	183.1

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section
SAND - ASPHALT STABILIZATION

Project: Marchand
Date Started: Oct. 2, 1961
Date Completed: Oct. 21, 1961

Test: Freeze - Thaw
Type of Asphalt: 150-200 Pen.
Type of Additive: Lime

Date	Wt.	Temp.		2-3-2	2-3-3		3-3-2	3-3-3		4-3-2	4-3-3		5-3-2	5-3-3		6-3-2	6-3-3
10- 2	Air			417.7	420.0		433.7	434.2		430.1	438.3		433.9	433.0		460.3	456.1
2	Water			160.1	161.8		173.8	175.1		176.0	180.8		177.2	175.6		204.5	201.2
3	Air	-7°C		418.2	420.0		434.5	435.7		431.0	439.2		435.1	434.2		461.2	457.7
4	Air	-7°C		418.2	419.6		434.2	435.6		431.5	439.3		435.0	434.7		461.1	458.1
5	Air	-7°C		417.5	418.8		434.5	434.9		431.1	439.2		434.6	433.8		460.9	457.5
6	Air	-7°C		417.5	418.5		434.7	435.2		431.3	438.6		435.4	434.1		461.0	457.1
7	Air	-8°C		417.2	418.5		434.0	436.3		430.9	438.8		434.7	433.5		461.0	457.1
8	Air	-8°C		417.2	418.6		434.4	436.5		431.7	439.2		435.6	434.5		461.7	457.8
8	Water			161.3	162.8		175.5	177.6		177.7	182.1		178.8	177.1		206.3	203.0
14	Air	-8°C		417.0	418.4		434.0	436.4		431.5	439.1		435.5	434.7		461.5	457.7
15	Air	-8°C		417.0	418.2		434.1	436.3		431.2	439.0		435.3	434.5		461.3	457.6
16	Air	-6°C		416.2	418.2		435.0	436.3		432.1	439.5		436.2	434.5		462.2	457.5
17	Air	-8°C		416.5	418.6		435.1	437.2		432.0	439.5		435.8	434.4		461.3	457.3
18	Air	-8°C		415.5	418.0		435.4	437.0		432.1	439.7		436.1	435.0		462.1	458.4
19	Air	-9°C		414.9	417.5		434.5	436.3		431.1	438.5		435.0	433.5		461.0	456.8
20	Air	-7°C		415.1	417.5		434.3	436.1		431.8	439.7		436.2	434.7		461.8	457.9
20	Water			160.0	163.1		174.6	177.0		178.2	182.0		179.3	178.0		205.4	203.8

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

SAND - ASPHALT STABILIZATION

Project: Marchand

Date Started: Sept. 25, 1961

Date Completed: Nov 6, 1961

Test: Water Immersion

Type of Asphalt: SS-1

Type of Additive: None

Date	Weight	2-0-6	2-0-5	2-0-4	3-0-6	3-0-5	3-0-4	4-0-6	4-0-5	4-0-4	5-0-6	5-0-5	5-0-4	6-0-6	6-0-5	6-0-4
9-25	Air	403.9	405.2	406.7	414.0	416.5	417.4	430.9	430.2	428.7	448.2	446.5	446.8	453.1	450.9	455.0
	Water	149.7	150.5	150.9	159.3	160.8	160.9	175.3	174.8	173.5	194.0	192.8	193.0	197.9	196.5	199.8
10-3	Air	437.3	438.4	440.0	431.5	433.6	434.1	449.8	448.1	446.5	465.4	464.0	464.1	468.3	467.1	469.6
	Water	181.5	188.3	185.1	174.8	176.6	177.4	192.0	191.4	190.0	210.3	208.7	209.7	210.0	210.0	213.0
10-5	Air	439.5	441.5	439.0	432.5	437.0	438.0	450.5	450.0	451.0	468.0	467.0	468.5	469.0	469.0	472.0
10-11	Air	443.0	448.0	445.0	447.0	452.0	452.0	467.0	466.0	465.0	482.0	482.0	482.0	479.0	478.0	483.0
10-18	Air	459.0	458.0	460.0	462.0	463.0	463.0	480.0	479.0	480.0	495.0	493.0	492.0	493.0	491.0	492.0
	Water	203.7	203.0	206.6	206.0	208.1	204.4	223.6	224.0	224.1	238.9	236.3	237.0	237.7	235.8	237.2
10-26	Air	450.0	450.0	--	477.0	483.0	480.0	493.0	497.0	490.0	510.0	513.0	505.0	500.0	499.0	505.0
11-1	Air	436.0	441.0	--	478.0	488.0	485.0	498.0	500.0	495.0	515.0	516.0	510.0	505.0	505.0	510.0
11-6	Air	--	--	--	482.1	491.1	488.0	499.5	502.4	497.2	516.5	516.0	513.2	508.6	508.6	512.1
	Water	--	--	--	226.9	234.5	232.2	243.5	247.0	241.2	262.0	261.0	258.0	252.2	252.2	236.7

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section
SAND - ASPHALT STABILIZATION

Project: Marchand
Date Started: Sept. 25, 1961
Date Completed: Nov. 6, 1961

Test: Water Immersion
Type of Asphalt: SS-1
Type of Additive: 1% Lime

Date	Weight	2-1-6	2-1-5	2-1-4	3-1-6	3-1-5	3-1-4	4-1-6	4-1-5	4-1-4	5-1-6	5-1-5	5-1-4	6-1-6	6-1-5	6-1-4
9-25	Air	418.7	419.1	418.1	424.0	422.8	422.1	440.5	441.7	441.5	457.1	456.1	457.9	459.7	454.1	456.7
	Water	163.1	163.1	163.1	168.9	168.3	167.3	185.0	186.1	185.5	203.0	203.1	203.3	204.7	200.8	203.2
10-3	Air	435.8	434.4	434.1	438.5	437.5	436.0	456.0	457.3	457.0	472.0	471.6	472.4	468.4	466.0	471.5
	Water	179.3	179.1	179.2	181.8	182.0	180.6	199.1	200.4	200.2	217.6	217.2	217.5	212.7	211.9	216.5
10-5	Air	434.0	434.5	434.0	438.0	438.0	438.0	456.0	457.5	458.5	473.5	473.0	475.0	469.0	467.0	473.0
10-11	Air	442.0	445.0	443.0	448.0	450.0	448.0	464.0	468.0	469.0	484.0	485.0	485.0	477.0	475.0	481.0
10-18	Air	447.0	446.0	449.0	467.0	471.0	469.0	482.0	484.0	479.0	498.0	501.0	496.0	491.0	490.0	495.0
	Water	201.5	205.2	204.2	206.1	214.5	212.1	225.1	227.6	222.4	242.4	245.3	240.7	233.6	232.9	238.7
10-26	Air	458.0	455.0	457.0	469.0	470.0	469.0	490.0	490.0	493.0	504.0	503.0	505.0	495.0	490.0	499.0
11-1	Air	458.0	457.0	458.0	472.0	474.0	472.0	495.0	495.0	498.0	506.0	508.0	508.0	500.0	496.0	505.0
11-6	Air	462.0	458.6	459.3	475.7	477.7	474.4	498.2	498.0	500.3	508.7	509.0	510.5	502.9	500.0	508.0
	Water	209.4	207.3	208.7	221.0	223.1	220.3	242.8	243.0	245.6	253.6	255.4	255.0	249.5	246.7	253.6

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section
SAND - ASPHALT STABILIZATION

Project: Marchand
Date Started: Sept. 25, 1961
Date Completed: Nov. 6, 1961

Test: Water Immersion
Type of Asphalt: SS-1
Type of Additive: 3% Lime

Date	Weight	2-3-6	2-3-5	2-3-4	3-3-6	3-3-5	3-3-4	4-3-6	4-3-5	4-3-4	5-3-6	5-3-5	5-3-4	6-3-6	6-3-5	6-3-4
9-25	Air	424.9	421.4	425.5	432.6	434.1	428.5	447.2	450.0	447.5	463.1	459.0	459.9	465.2	464.4	463.4
	Water	168.3	166.1	170.0	177.8	179.5	174.9	192.9	195.2	192.5	208.0	204.7	205.3	211.2	210.9	210.1
10-3	Air	448.6	443.3	447.8	446.7	447.2	442.4	461.6	464.4	462.2	478.7	475.2	475.8	476.9	476.0	477.2
	Water	192.0	188.1	192.6	190.9	192.0	188.5	207.3	209.6	207.5	222.7	219.9	220.6	222.0	220.8	222.0
10-5	Air	448.0	443.5	448.0	447.0	448.5	443.5	462.5	464.5	463.5	480.0	476.0	477.5	477.5	476.0	477.5
10-11	Air	454.0	450.0	453.0	454.0	455.0	455.0	470.0	472.0	470.0	489.0	485.0	485.0	485.0	483.0	485.0
10-18	Air	451.0	451.0	452.0	460.0	461.0	460.0	479.0	482.0	482.0	495.0	495.0	496.0	486.0	490.0	490.0
	Water	197.8	197.8	198.8	204.1	206.7	204.4	222.3	224.5	224.6	238.9	240.7	240.5	231.1	229.1	234.8
10-26	Air	463.0	462.0	464.0	468.0	470.0	465.0	485.0	485.0	486.0	500.0	497.0	497.0	500.0	497.0	498.0
11-1	Air	465.0	465.0	467.0	471.0	474.0	468.0	489.0	489.0	490.0	502.0	500.0	499.0	502.0	500.0	502.0
11-6	Air	466.0	467.6	468.5	475.1	478.9	471.8	493.5	492.4	494.7	504.1	501.6	500.5	504.5	501.9	504.0
	Water	213.1	214.4	215.8	220.5	224.9	208.9	239.3	238.0	240.6	248.9	246.7	246.7	250.0	248.7	250.4

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section
SAND - ASPHALT STABILIZATION

Project: Marchand
Date Started: Sept. 27, 1961
Date Completed: Nov. 8, 1961

Test: Water Immersion
Type of Asphalt: 150-200 Pen
Type of Additive: None

Date	Weight	2-0-6	2-0-5	2-0-4	3-0-6	3-0-5	3-0-4	4-0-6	4-0-5	4-0-4	5-0-6	5-0-5	5-0-4	6-0-6	6-0-5	6-0-4
9-27	Air	408.7	410.1	407.8	427.7	423.8	429.5	427.3	429.6	430.7	429.6	430.0	428.3	436.2	435.0	433.6
	Water	153.7	154.8	151.8	172.2	169.5	173.0	173.2	173.3	176.0	174.9	174.2	174.0	181.5	180.0	179.4
10-3	Air	420.0	421.3	418.8	433.8	436.5	440.0	437.4	440.3	442.1	440.0	440.0	438.3	444.5	444.4	443.0
	Water	164.3	165.0	162.5	182.2	179.6	182.7	183.0	183.8	185.8	184.6	183.9	183.6	190.0	182.8	187.9
10-5	Air	421.0	422.0	420.0	441.0	437.0	442.0	440.0	442.0	444.0	442.0	443.0	440.0	445.0	447.0	444.0
10-11	Air	430.0	433.0	430.0	453.0	448.0	454.0	448.0	450.0	451.0	451.0	455.0	455.0	457.0	459.0	453.0
10-18	Air	440.0	445.0	441.0	465.0	460.0	465.0	458.0	459.0	461.0	460.0	462.0	457.0	461.0	465.0	461.0
	Water	183.2	188.4	184.9	207.8	202.6	208.0	202.1	202.4	204.4	203.8	205.7	203.0	205.2	208.6	205.8
10-26	Air	445.0	452.0	448.0	472.0	466.0	473.0	465.0	465.0	467.0	465.0	467.0	463.0	466.0	470.0	466.0
11-1	Air	450.0	453.0	450.0	475.0	470.0	475.0	469.0	470.0	472.0	470.0	470.0	468.0	470.0	470.0	468.0
11-8	Air	458.4	461.3	460.0	478.3	474.7	479.7	472.1	472.9	475.0	472.5	473.2	471.0	472.2	473.4	470.4
	Water	204.3	205.5	205.0	222.2	208.5	222.7	217.6	217.5	219.7	217.1	217.0	216.5	217.7	218.3	215.7

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section
SAND - ASPHALT STABILIZATION

Project: Marchand
Date Started: Sept. 27, 1961
Date Completed: Nov. 8, 1961

Test: Water Immersion
Type of Asphalt: 150-200 Pen
Type of Additive: 1% Lime

Date	Weight	2-1-6	2-1-5	2-1-4	3-1-6	3-1-5	3-1-4	4-1-6	4-1-5	4-1-4	5-1-6	5-1-5	5-1-4	6-1-6	6-1-5	6-1-4
9-27	Air	415.6	418.1	419.6	430.0	431.3	431.1	430.8	433.1	430.0	424.8	426.1	427.6	439.5	437.3	436.1
	Water	160.4	162.4	163.6	172.7	174.7	174.1	175.8	176.9	173.8	171.1	172.2	173.3	183.1	180.4	180.0
10-3	Air	426.8	429.5	430.0	439.7	442.7	441.7	441.1	443.1	440.0	433.8	434.9	436.1	447.0	446.2	446.1
	Water	171.2	173.3	174.1	182.6	185.0	183.9	186.4	187.3	184.3	180.0	181.4	182.0	190.9	189.7	189.2
10-5	Air	427.0	429.0	430.5	440.0	442.5	442.0	442.5	443.5	442.5	435.0	437.0	437.0	448.5	449.0	447.0
10-11	Air	433.0	435.0	436.0	448.0	449.0	448.0	449.0	450.0	449.0	442.0	446.0	443.0	455.0	457.0	455.0
10-18	Air	441.0	445.0	445.0	457.0	458.0	458.0	459.0	460.0	459.0	451.0	455.0	452.0	465.0	466.0	463.0
	Water	185.7	188.5	188.4	199.6	200.7	200.0	203.7	202.9	202.3	196.4	200.5	198.0	207.7	208.5	206.5
10-26	Air	448.0	452.0	451.0	463.0	465.0	465.0	466.0	465.0	465.0	457.0	461.0	458.0	471.0	471.0	468.0
11-1	Air	451.0	457.0	454.0	467.0	469.0	469.0	470.0	470.0	469.0	461.0	465.0	463.0	475.0	475.0	472.0
11-8	Air	458.7	460.6	461.5	474.5	473.4	475.0	474.5	475.1	475.5	467.0	470.0	468.2	482.7	481.7	479.0
	Water	203.8	205.2	206.4	217.9	217.7	218.1	209.8	220.7	220.4	214.5	217.0	215.7	226.2	224.8	223.3

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section
SAND - ASPHALT STABILIZATION

Project: Marchand
Date Started: Sept. 27, 1961
Date Completed: Nov. 8, 1961

Test: Water Immersion
Type of Asphalt: 150-200 Pen
Type of Additive: 3% Lime

Date	Weight	2-3-6	2-3-5	2-3-4	3-3-6	3-3-5	3-3-4	4-3-6	4-3-5	4-3-4	5-3-6	5-3-5	5-3-4	6-3-6	6-3-5	6-3-4
9-27	Air	420.4	418.4	419.0	434.9	435.5	433.7	433.5	435.5	436.5	439.0	435.5	434.4	455.3	456.8	457.3
	Water	162.8	162.0	161.4	176.1	176.7	175.2	177.7	178.7	179.6	180.2	178.5	177.0	200.0	201.2	201.0
10-3	Air	431.5	429.8	429.5	446.1	446.5	444.2	443.2	445.4	445.8	447.8	445.4	443.2	462.6	465.0	465.7
	Water	173.8	173.0	172.0	187.3	187.8	186.4	188.0	189.0	189.7	189.6	187.8	186.5	208.4	209.5	210.3
10-5	Air	433.0	430.0	430.5	446.0	447.0	445.0	444.0	446.0	446.0	448.5	445.0	445.0	464.0	467.0	467.0
10-11	Air	440.0	437.0	437.0	452.0	453.0	451.0	451.0	452.0	452.0	455.0	452.0	451.0	470.0	474.0	473.0
10-18	Air	448.0	445.0	445.0	460.0	460.0	458.0	460.0	460.0	461.0	464.0	460.0	460.0	479.0	481.0	480.0
	Water	189.5	187.5	187.4	200.7	200.7	199.0	203.0	203.7	204.4	205.5	202.8	201.9	223.3	224.5	224.6
10-26	Air	451.0	448.0	450.0	465.0	465.0	463.0	465.0	466.0	467.0	470.0	466.0	465.0	484.0	486.0	485.0
11-1	Air	453.0	451.0	452.0	466.0	466.0	465.0	467.0	468.0	469.0	472.0	469.0	467.0	487.0	488.0	488.0
11-8	Air	457.0	454.3	456.7	469.5	470.6	469.6	471.4	472.6	474.0	476.8	473.5	473.8	489.9	493.4	491.2
	Water	200.3	198.4	199.4	211.1	211.8	211.2	216.1	217.0	218.3	219.4	217.7	216.8	235.2	238.0	236.8

SAND-ASPHALT STABILIZATION

RATE OF WATER ABSORPTION

SS-1 Emulsion

	Soaking Time (Days)	Residual Asphalt Content - (%) 2	3	4	5	6
0% Lime	8	33.3	17.1	18.2	17.3	15.3
	10	34.7	19.9	20.6	20.7	17.0
	16	40.1	34.4	36.1	34.8	27.0
	23	53.7	46.7	49.7	46.2	39.0
	31	----	64.1	60.1	62.2	48.4
	37	----	67.7	67.8	66.5	53.7
	43	----	71.1	69.8	68.0	56.8
1% Lime	8	16.1	14.3	15.5	15.0	12.0
	10	15.5	15.0	16.1	16.8	13.1
	16	24.7	25.7	25.8	27.6	20.8
	23	28.7	46.0	40.4	41.3	35.2
	31	38.1	46.4	49.8	47.0	37.8
	37	39.0	49.7	54.8	50.3	43.5
	43	41.4	52.6	57.6	52.4	46.8
3% Lime	8	22.6	13.6	14.5	15.9	12.4
	10	22.5	14.6	15.3	17.2	12.7
	16	28.4	22.9	22.4	25.7	20.0
	23	27.4	28.6	32.8	34.7	24.3
	31	39.1	35.9	37.1	37.3	34.0
	37	41.7	39.3	41.0	39.7	37.0
	43	43.5	43.6	45.3	41.4	39.2

Note: All values given in the body of this table indicate the number of grams of water absorbed by the samples. All weights are the average of three samples.

SAND-ASPHALT STABILIZATION

VOIDS - % FILLED WITH WATER

SS-1 Emulsion

	Soaking Time (Days)	Residual Asphalt Content - (%) 2	3	4	5	6
0% Lime	8	32.2	16.9	18.6	18.6	16.5
	10	33.5	19.6	21.1	22.3	18.4
	16	38.7	33.9	36.9	37.4	29.2
	23	51.9	46.1	50.8	49.7	42.2
	31	----	63.2	61.4	66.9	52.3
	37	----	66.8	69.3	71.5	58.0
	43	----	70.1	71.4	73.1	61.4
1% Lime	8	16.0	14.2	16.3	16.5	12.9
	10	15.4	14.9	16.9	18.4	14.1
	16	24.6	25.6	27.1	30.3	22.4
	23	28.6	45.8	42.4	45.3	37.9
	31	37.9	46.2	52.3	51.6	40.7
	37	38.8	49.5	57.6	55.2	46.9
	43	41.2	52.4	60.5	57.5	50.4
3% Lime	8	22.3	13.6	15.1	17.1	13.3
	10	22.2	14.6	16.0	18.5	13.6
	16	28.0	22.9	23.4	27.7	21.5
	23	27.0	28.6	34.2	37.4	26.1
	31	38.5	35.9	38.7	40.2	36.5
	37	41.1	39.3	42.8	42.8	39.7
	43	42.9	43.6	47.3	44.6	42.1

Note: All values given in the body of this table indicate the percentage of the void space in the aggregate that is filled with water. The values shown are the average of three specimens.

SAND-ASPHALT STABILIZATION

RATE OF WATER ABSORPTION

150-200 Pen. Asphalt Cement

	Soaking Time (Days)	Residual Asphalt Content - (%) 2	3	4	5	6
0% Lime	6	11.2	11.3	10.7	10.1	9.0
	8	12.1	13.0	12.8	12.0	10.4
	14	22.1	24.7	20.4	24.4	21.4
	21	33.1	36.3	30.1	30.4	27.4
	29	39.5	43.3	36.5	35.7	32.4
	35	46.1	46.3	41.1	40.0	34.4
	42	51.0	50.7	44.1	42.5	37.1
1% Lime	6	11.0	10.6	10.1	8.8	8.8
	8	11.1	10.7	11.5	10.2	10.5
	14	16.9	17.5	18.1	17.5	18.0
	21	25.9	26.9	28.0	26.5	27.0
	29	32.9	33.5	34.1	32.5	32.3
	35	36.2	37.5	38.4	36.8	36.4
	42	42.5	43.5	43.7	42.2	43.5
3% Lime	6	11.0	10.9	9.3	9.2	8.0
	8	11.9	11.3	10.2	9.9	9.5
	14	18.7	17.3	16.5	16.4	15.9
	21	26.7	24.6	25.2	25.1	23.5
	29	30.4	29.6	30.8	30.7	28.5
	35	32.7	31.0	32.8	33.0	31.2
	42	36.7	35.2	37.5	38.4	35.0

Note: All values given in the body of this table indicate the number of grams of water absorbed by the samples. All weights are the average of three samples.

SAND-ASPHALT STABILIZATION

% VOIDS FILLED WITH WATER

150-200 Pen. Asphalt Cement

	Soaking Time (Days)	Residual Asphalt Content - (%) 2	3	4	5	6
0% Lime	6	10.9	11.6	10.9	10.2	9.1
	8	11.8	13.3	13.0	12.1	10.5
	14	21.5	25.4	20.8	24.5	21.6
	21	32.3	37.3	30.7	30.6	27.7
	29	38.5	44.5	37.2	35.9	32.7
	35	44.9	47.5	41.9	40.2	34.7
	42	49.7	52.0	45.0	42.8	37.5
1% Lime	6	10.9	10.9	10.2	8.6	8.8
	8	11.0	11.0	11.7	10.0	10.6
	14	16.8	17.9	18.3	17.1	18.1
	21	25.7	27.6	28.4	26.0	27.1
	29	32.6	34.3	34.5	31.8	32.5
	35	35.9	38.4	38.9	36.0	36.6
	42	42.2	44.6	44.3	41.3	43.7
3% Lime	6	10.7	11.0	9.3	9.1	8.4
	8	11.5	11.4	10.2	9.8	9.9
	14	18.1	17.5	16.4	16.2	16.6
	21	25.9	24.8	25.1	24.8	24.6
	29	29.5	29.9	30.7	30.3	29.8
	35	31.7	31.3	32.7	32.5	32.6
	42	35.6	35.5	37.4	37.9	36.6

Note: All values given in the body of this table indicate the percentage of the void space in the aggregate that is filled with water. The values shown are the average of three specimens.

APPENDIX "E"

MODIFIED HUBBARD-FIELD STABILITY TESTS

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

HUBBARD-FIELD STABILITY TEST

Project: Marchand   Additive: Lime   Amount: 0 %
Specific Gravity of Agg: 2.63   Curing Period: Air Dried
Specific Gravity of AC: 1.00
Date: 28-9-61   Tested By: J.A.K.   Type of Asphalt: 150-200 Pen.

Sample No.	% AC (Agg)	% AC (Mix)	Wet Weight (gms.)	Dry Weight (gms.)	Weight in Water	Bulk Volume (cc)	Weight of Water	Moisture Content (%)	Density of Mix (pcf)	Loading Time (sec)	H-F Stability (pounds)
	6.0	5.66		100.0	43.3					30	480
	6.0	5.66		100.1	43.3					27	500
	6.0	5.66		100.0	43.0					27	520
AVG				100.0	43.2	56.8			109.9		500
	5.0	4.76		99.4	42.6					26	500
	5.0	4.76		98.8	42.3					24	505
	5.0	4.76		100.1	42.7					25	490
AVG				99.4	42.5	56.9			109.1		498
	4.0	3.85		100.2	43.0					23	490
	4.0	3.85		100.0	42.6					27	485
	4.0	3.85		100.0	42.7					25	465
AVG				100.1	42.8	57.3			109.1		480
	3.0	2.91		99.3	41.4					30	470
	3.0	2.91		100.0	41.7					29	550
	3.0	2.91		100.1	42.0					28	660
AVG				99.8	41.7	58.1			107.3		560
	2.0	1.96		100.0	40.0					25	260
	2.0	1.96		100.1	40.1					28	275
	2.0	1.96		99.1	39.8					24	280
AVG				99.7	40.0	59.7			104.3		272

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

HUBBARD-FIELD STABILITY TEST

Project: Marchand
Additive: Lime Amount: 1 %
Specific Gravity of Agg: 2.63
Curing Period: Air Dried
Specific Gravity of AC: 1.00
Date: 28-9-61 Tested By: J.A.K. Type of Asphalt: 150-200 Pen.

Sample No.	% AC (Agg)	% AC (Mix)	Wet Weight (gms.)	Dry Weight (gms.)	Weight in Water	Bulk Volume (cc)	Weight of Water	Moisture Content (%)	Density of Mix (pcf)	Loading Time (sec)	H-F Stability (pounds)
	6.0	5.66		100.6	43.7					33	560
	6.0	5.66		100.0	42.8					30	520
	6.0	5.66		100.8	43.7					29	560
AVG				100.5	43.4	57.1			109.9		547
	5.0	4.76		99.7	42.2					26	425
	5.0	4.76		99.8	42.3					25	400
	5.0	4.76		100.0	42.6					26	550
AVG				99.8	42.4	57.4			108.6		458
	4.0	3.85		100.5	43.1					30	450
	4.0	3.85		100.1	42.9					26	445
	4.0	3.85		99.7	42.9					26	445
AVG				100.1	43.0	57.1			109.4		446
	3.0	2.91		99.6	42.0					27	605
	3.0	2.91		100.0	42.3					32	605
	3.0	2.91		99.8	41.8					25	585
AVG				99.8	42.0	57.8			107.8		598
	2.0	1.96		99.1	40.3					25	340
	2.0	1.96		100.1	40.7					24	330
	2.0	1.96		100.4	41.1					24	355
AVG				99.9	40.7	59.2			105.4		342

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

HUBBARD-FIELD STABILITY TEST

Project: Marchand
Specific Gravity of Agg: 2.63
Specific Gravity of AC: 1.00
Date: 28-9-61 Tested By: J.A.K.
Additive: Lime Amount: 3 %
Curing Period: Air Dried
Type of Asphalt: 150-200 Pen.

Sample No.	% AC (Agg)	% AC (Mix)	Wet Weight (gms.)	Dry Weight (gms.)	Weight in Water	Bulk Volume (cc)	Weight of Water	Moisture Content (%)	Density of Mix (pcf)	Loading Time (sec)	H-F Stability (pounds)
	6.0	5.66		100.9	46.0						675
	6.0	5.66		99.7	45.4					34	700
	6.0	5.66		100.0	45.5					37	830
AVG				100.2	45.6	54.6			114.6		735
	5.0	4.76		100.0	43.2					32	595
	5.0	4.76		102.5	44.2					31	600
	5.0	4.76		99.8	42.7					39	770
AVG				100.8	43.4	57.4			109.6		655
	4.0	3.85		98.6	42.9						795
	4.0	3.85		100.1	43.0					35	645
	4.0	3.85		101.0	43.4					35	630
AVG				100.2	43.1	57.1			109.6		690
	3.0	2.91		100.0	42.9					30	885
	3.0	2.91		99.4	42.4					29	670
	3.0	2.91		100.0	42.6					31	695
AVG				99.8	42.6	57.2			108.9		750
	2.0	1.96		100.2	40.6					39	335
	2.0	1.96		99.4	40.0					34	340
	2.0	1.96		100.0	40.5					26	380
AVG				99.9	40.4	59.5			104.8		352

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

HUBBARD-FIELD STABILITY TEST

Project: Marchand
Additive: None Amount: 0 %
Specific Gravity of Agg: 2.63
Curing Period: Air Dried
Specific Gravity of AC: 1.00
Date: 28-9-61 Tested By: J.A.K. Type of Asphalt: SS-1

Sample No.	% AC (Agg)	% AC (Mix)	Wet Weight (gms.)	Dry Weight (gms.)	Weight in Water	Bulk Volume (cc)	Weight of Water	Moisture Content (%)	Density of Mix (pcf)	Loading Time (sec)	H-F Stability (pounds)
	6.0	5.66		98.9	45.1					30	590
	6.0	5.66		100.1	45.9					28	640
	6.0	5.66		100.6	46.3					29	610
AVG				99.9	45.8	54.1			115.3		613
	5.0	4.76		99.6	44.9					30	500
	5.0	4.76		100.0	45.3					30	575
	5.0	4.76		99.2	44.8					36	570
AVG				99.6	45.0	54.6			113.9		548
	4.0	3.85		100.0	42.9					25	615
	4.0	3.85		100.0	43.1					34	595
	4.0	3.85		99.1	42.7					33	590
AVG				99.7	42.9	56.8			109.6		600
	3.0	2.91		100.3	41.1					24	505
	3.0	2.91		99.9	40.8					27	495
	3.0	2.91		100.6	41.0					23	495
AVG				100.3	41.0	59.3			105.6		498
	2.0	1.96		97.3	38.6					29	270
	2.0	1.96		97.3	38.3					29	280
	2.0	1.96		97.0	38.5					25	330
AVG				97.2	38.5	58.7			103.4		293

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

HUBBARD-FIELD STABILITY TEST

Project: Marchand Additive: Lime Amount: 1.0 %

Specific Gravity of Agg: 2.63 Curing Period: Air Dried

Specific Gravity of AC: 1.00

Date: 28-9-61 Tested By: J.A.K. Type of Asphalt: SS-1

Sample No.	% AC (Agg)	% AC (Mix)	Wet Weight (gms.)	Dry Weight (gms.)	Weight in Water	Bulk Volume (cc)	Weight of Water	Moisture Content (%)	Density of Mix (pcf)	Loading Time (sec)	H-F Stability (pounds)
	6.0	5.66		100.0	46.7					32	550
	6.0	5.66		100.0	46.6					37	480
	6.0	5.66		100.0	46.3					34	500
AVG				100.0	46.5	53.5			116.7		510
	5.0	4.76		98.8	44.9					52	555
	5.0	4.76		98.7	45.1					49	575
	5.0	4.76		98.6	45.1					49	575
AVG				98.7	45.1	53.6			114.9		568
	4.0	3.85		100.0	44.0					49	660
	4.0	3.85		100.0	44.0					39	455
	4.0	3.85		100.1	44.3					41	710
AVG				100.0	44.1	55.9			111.7		608
	3.0	2.91		99.7	41.7					43	295
	3.0	2.91		100.2	42.0					41	305
	3.0	2.91		100.1	41.8					36	300
AVG				100.0	41.8	58.2			107.3		300
	2.0	1.96		96.9	39.6					35	285
	2.0	1.96		97.3	40.0					37	410
	2.0	1.96		96.8	40.0					36	285
AVG				97.0	39.9	57.1			106.1		327

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

HUBBARD-FIELD STABILITY TEST

Project: Marchand | Additive: Lime | Amount: 3.0 %

Specific Gravity of Agg: 2.63 | Curing Period: Air Dried

Specific Gravity of AC: 1.00

Date: 26-9-61 | Tested By: J.A.K. | Type of Asphalt: SS-1

Sample No.	% AC (Agg)	% AC (Mix)	Wet Weight (gms.)	Dry Weight (gms.)	Weight in Water	Bulk Volume (cc)	Weight of Water	Moisture Content (%)	Density of Mix (pcf)	Loading Time (sec)	H-F Stability (pounds)
	6.0	5.66		100.0	47.5					61	590
	6.0	5.66		99.6	46.7					60	1075
	6.0	5.66		100.2	47.6					58	1125
AVG				99.9	47.3	52.6			118.6		930
	5.0	4.76		98.5	46.3					49	1455
	5.0	4.76		98.8	46.6					47	1450
	5.0	4.76		98.3	46.5					42	1495
AVG				98.5	46.5	52.0			118.2		1467
	4.0	3.85		99.3	45.0					38	990
	4.0	3.85		98.2	44.7					34	1115
	4.0	3.85		99.7	45.4					40	1555
AVG				99.1	45.0	54.1			114.4		1220
	3.0	2.91		97.5	42.3					35	960
	3.0	2.91		97.8	42.6					30	740
	3.0	2.91		97.7	42.6					32	700
AVG				97.7	42.5	55.2			110.5		800
	2.0	1.96		96.4	40.9					22	460
	2.0	1.96		95.5	40.2					23	440
	2.0	1.96		95.6	40.2					24	430
AVG				95.8	40.4	55.4			107.9		443

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

HUBBARD-FIELD STABILITY TEST

Project: Marchand
Specific Gravity of Agg: 2.63
Specific Gravity of AC: 1.00
Date: 7-11-61 Tested By: JAK

Additive: None Amount: 0 %
Curing Period: Water Immersion
Type of Asphalt: 150-200 Pen.

Sample No.	% AC (Agg)	% AC (Mix)	Wet Weight (gms.)	Dry Weight (gms.)	Weight in Water	Bulk Volume (cc)	Weight of Water	Moisture Content (%)	Density of Mix (pcf)	Loading Time (sec)	H-F Stability (pounds)
	6.0	5.66	108.5	101.2	51.7					51	395
	6.0	5.66	109.8	100.8	52.5					49	480
	6.0	5.66	108.3	100.2	51.6					50	365
AVG			108.9	100.7	51.9	57.0	8.2	8.1	110.3		413
	5.0	4.76	108.5	102.1	52.1					43	400
	5.0	4.76	107.8	103.7	51.6					42	410
	5.0	4.76	108.4	100.4	51.6					49	420
AVG			108.2	102.1	51.8	56.4	6.1	6.0	113.0		410
	4.0	3.85	110.0	99.7	52.7					37	330
	4.0	3.85	110.2	100.9	53.0					40	330
	4.0	3.85	109.7	99.0	52.4					36	305
AVG			110.0	99.9	52.7	57.3	10.1	10.1	108.8		322
	3.0	2.91	111.6	100.5	54.5					33	320
	3.0	2.91	111.3	99.9	54.1					37	320
	3.0	2.91	112.7	100.0	54.8					39	320
AVG			111.9	100.1	54.5	57.4	11.8	11.8	108.9		320
	2.0	1.96	110.3	99.3	51.9					34	270
	2.0	1.96	113.1	100.9	53.6					38	210
	2.0	1.96	112.8	98.5	53.2					30	210
AVG			112.1	99.6	52.9	59.2	12.5	12.6	105.0		230

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

HUBBARD-FIELD STABILITY TEST

Project: Marchand
Additive: Lime Amount: 1 %
Specific Gravity of Agg: 2.63
Curing Period: Water Immersion
Specific Gravity of AC: 1.00
Date: 7-11-61 Tested By: JAK Type of Asphalt: 150-200 Pen.

Sample No.	% AC (Agg)	% AC (Mix)	Wet Weight (gms.)	Dry Weight (gms.)	Weight in Water	Bulk Volume (cc)	Weight of Water	Moisture Content (%)	Density of Mix (pcf)	Loading Time (sec)	H-F Stability (pounds)
	6.0	5.66	110.5	100.9	53.0					60	390
	6.0	5.66	111.9	101.7	54.0					53	625
	6.0	5.66	110.0	99.9	53.1					57	675
AVG			110.8	100.8	53.4	57.4	10.0	9.9	109.6		563
	5.0	4.76	110.0	99.4	53.1					46	700
	5.0	4.76	109.6	99.6	52.5					46	765
	5.0	4.76	110.0	99.5	52.9					45	775
AVG			109.9	99.5	52.8	57.1	10.4	10.5	108.8		747
	4.0	3.85	109.0	98.9	53.1					49	670
	4.0	3.85	109.4	98.7	52.9					46	670
	4.0	3.85	112.7	101.9	54.6					47	630
AVG			110.4	99.8	52.9	57.5	10.6	10.6	108.4		657
	3.0	2.91	110.6	99.2	53.3					47	550
	3.0	2.91	111.9	100.6	53.9					47	660
	3.0	2.91	111.5	100.0	53.6					47	665
AVG			111.3	99.9	53.6	57.7	11.4	11.4	108.1		625
	2.0	1.96	110.3	99.6	51.4					44	440
	2.0	1.96	109.9	99.1	50.9					41	450
	2.0	1.96	110.6	99.5	51.8					45	405
AVG			110.3	99.4	51.4	58.9	10.9	11.0	105.4		432

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section
HUBBARD-FIELD STABILITY TEST

Project: Marchand | Additive: Lime | Amount: 3 %
Specific Gravity of Agg: 2.63 | Curing Period: Water Immersion
Specific Gravity of AC: 1.00
Date: 7-11-61 | Tested By: JAK | Type of Asphalt: 150-200 Pen.

Sample No.	% AC (Agg)	% AC (Mix)	Wet Weight (gms.)	Dry Weight (gms.)	Weight in Water	Bulk Volume (cc)	Weight of Water	Moisture Content (%)	Density of Mix (pcf)	Loading Time (sec)	H-F Stability (pounds)
	6.0	5.66	109.6	100.3	54.7					63	1025
	6.0	5.66	109.1	101.5	54.2					60	1090
	6.0	5.66	108.3	99.6	53.7					59	1105
AVG			109.0	100.5	54.2	54.8	8.5	8.4	114.5		1073
	5.0	4.76	111.1	99.6	53.2					56	855
	5.0	4.76	113.5	99.0	54.7					54	850
	5.0	4.76	109.5	99.6	52.4					57	1120
AVG			111.4	99.4	53.4	58.0	12.0	12.1	107.0		958
	4.0	3.85	108.9	99.6	52.1					56	890
	4.0	3.85	110.4	100.1	53.0					58	985
	4.0	3.85	108.3	99.4	52.1					55	970
AVG			109.2	99.7	52.4	56.8	9.5	9.5	109.6		948
	3.0	2.91	108.2	99.0	51.2					52	950
	3.0	2.91	107.6	98.8	50.5					49	1130
	3.0	2.91	107.4	99.7	50.7					52	1130
AVG			107.7	99.5	50.8	56.9	8.2	8.2	109.2		1070
	2.0	1.96	108.6	99.2	49.8					38	600
	2.0	1.96	109.6	99.3	50.1					38	610
	2.0	1.96	107.7	97.5	49.6					35	420
AVG			108.6	98.7	49.8	58.8	9.9	10.0	104.8		543

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

HUBBARD-FIELD STABILITY TEST

Project: Marchand
Specific Gravity of Agg: 2.63
Specific Gravity of AC: 1.00
Date: 7-11-61 Tested By: JAK
Additive: None Amount: 0 %
Curing Period: Water Immersion
Type of Asphalt: SS-1

Sample No.	% AC (Agg)	% AC (Mix)	Wet Weight (gms.)	Dry Weight (gms.)	Weight in Water	Bulk Volume (cc)	Weight of Water	Moisture Content (%)	Density of Mix (pcf)	Loading Time (sec)	H-F Stability (pounds)
	6.0	5.66	112.5	99.8	58.3					38	440
	6.0	5.66	111.3	98.3	57.5					39	465
	6.0	5.66	110.7	97.8	57.3					40	465
AVG			111.5	98.6	57.7	53.8	12.9	13.1	114.4		457
	5.0	4.76	113.0	98.8	58.4					39	430
	5.0	4.76	113.5	99.1	58.8					39	445
	5.0	4.76	113.5	99.2	58.8					37	445
AVG			113.3	99.0	58.7	54.6	14.3	14.5	113.2		440
	4.0	3.85	117.4	99.6	60.2					34	300
	4.0	3.85	117.2	99.8	60.2					36	295
	4.0	3.85	117.4	99.4	60.3					34	355
AVG			117.4	99.6	60.2	57.2	17.8	17.9	108.7		317
	3.0	2.91	119.9	99.6	60.5					35	310
	3.0	2.91	119.9	99.5	60.5					36	290
	3.0	2.91	119.8	99.6	60.5					36	290
AVG			119.9	99.6	60.5	59.4	20.3	20.4	104.7		297
	2.0	1.96	118.8	96.2	59.6					30	190
	2.0	1.96	118.2	95.8	59.1					31	120
	2.0	1.96	119.2	96.4	59.1					36	175
AVG			118.7	96.1	59.5	59.2	22.6	23.5	101.3		162

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

HUBBARD-FIELD STABILITY TEST

Project: Marchand   Additive: Lime   Amount: 1 %

Specific Gravity of Agg: 2.63   Curing Period: Water Immersion

Specific Gravity of AC: 1.00

Date: 7-11-61   Tested By: JAK   Type of Asphalt: SS-1

Sample No.	% AC (Agg)	% AC (Mix)	Wet Weight (gms.)	Dry Weight (gms.)	Weight in Water	Bulk Volume (cc)	Weight of Water	Moisture Content (%)	Density of Mix (pcf)	Loading Time (sec)	H-F Stability (pounds)
	6.0	5.66	112.5	100.3	58.7					45	800
	6.0	5.66	112.7	100.7	58.7					39	640
	6.0	5.66	112.8	100.6	59.0					40	835
AVG			112.7	100.5	58.8	53.9	12.2	12.1	116.4		758
	5.0	4.76	110.3	98.3	57.5					45	740
	5.0	4.76	111.3	99.3	57.2					49	770
	5.0	4.76	111.3	98.9	57.6					51	655
AVG			111.0	98.8	57.4	53.6	12.2	12.4	115.1		722
	4.0	3.85	114.9	100.4	58.7					41	650
	4.0	3.85	112.7	99.7	57.7					39	875
	4.0	3.85	114.9	100.1	58.8					45	905
AVG			114.2	100.1	58.4	55.8	14.1	14.1	112.0		810
	3.0	2.91	112.7	99.5	54.7					37	460
	3.0	2.91	114.0	100.3	55.4					40	455
	3.0	2.91	114.0	100.0	55.7					36	470
AVG			113.6	99.9	55.3	58.3	13.7	13.6	107.0		462
	2.0	1.96	111.9	97.1	54.2					30	330
	2.0	1.96	110.8	96.0	53.8					32	330
	2.0	1.96	108.8	95.3	52.2					35	510
AVG			110.5	96.1	53.4	57.1	14.4	15.0	105.1		390

PROVINCE OF MANITOBA
HIGHWAYS BRANCH
Materials and Research Section

HUBBARD-FIELD STABILITY TEST

Project: Marchand Additive: Lime Amount: 3 %
Specific Gravity of Agg: 2.63 Curing Period:
Specific Gravity of AC: 1.00 Water Immersion
Date: 7-11-61 Tested By: JAK Type of Asphalt: SS-1

Sample No.	% AC (Agg)	% AC (Mix)	Wet Weight (gms.)	Dry Weight (gms.)	Weight in Water	Bulk Volume (cc)	Weight of Water	Moisture Content (%)	Density of Mix (pcf)	Loading Time (sec)	H-F Stability (pounds)
	6.0	5.66	109.1	99.8	56.5					41	740
	6.0	5.66	110.2	100.8	56.9					46	950
	6.0	5.66	112.8	103.3	58.5					46	935
AVG			110.7	101.3	57.3	53.4	9.4	9.3	118.4		875
	5.0	4.76	109.7	98.2	58.0					48	1410
	5.0	4.76	110.8	98.8	57.8					45	1155
	5.0	4.76	109.3	97.4	57.9					50	1445
AVG			109.9	98.1	57.9	52.0	11.8	12.0	117.7		1337
	4.0	3.85	108.9	99.7	54.5					40	1120
	4.0	3.85	108.9	99.9	54.3					46	1530
	4.0	3.85	110.5	100.2	55.8					46	1475
AVG			109.4	99.9	54.9	54.5	9.5	9.5	114.4		1375
	3.0	2.91	108.0	99.1	51.8					39	740
	3.0	2.91	109.2	99.4	53.1					35	695
	3.0	2.91	109.3	99.5	52.7					36	700
AVG			108.8	99.3	52.5	56.3	9.5	9.6	110.1		712
	2.0	1.96	107.3	97.0	51.4					26	475
	2.0	1.96	106.7	96.0	51.2					31	875
	2.0	1.96	106.8	95.9	51.2					25	465
AVG			106.9	96.3	51.3	55.6	10.6	11.0	108.1		605

APPENDIX "F"

TRIAXIAL COMPRESSION TESTS ON SAND-EMULSION MIXTURES

TRIAXIAL COMPRESSION TESTS ON SAND-EMULSION MIX

SUMMARY OF STRESS CALCULATIONS

5% Residual Asphalt Content

Sample Number	Load Dial at 4% Strain	Load in Pounds	Corr. Area (in^2)	Deviator Stress (psi)	Confining Pressure (psi)	Vertical Stress (psi)
			3% Hydrated Lime			
1	680	163.2	3.27	49.8	20	69.8
2	503	120.7	3.27	36.9	10	46.9
3	990	237.6	3.27	72.7	30	102.7
4	1183	283.9	3.27	86.8	40	126.8
5	1378	330.7	3.27	101.1	50	151.1
7	600	145.4	3.27	44.4	10	54.4
8	1075	258.0	3.27	78.8	30	108.8
9	835	200.4	3.27	61.3	20	81.3
10	1407	337.7	3.27	103.3	50	153.3
11	760	182.4	3.27	55.8	10	65.8
12	1008	242.4	3.27	74.1	20	94.1
13	1158	277.9	3.27	85.0	30	115.0
14	1345	322.8	3.27	98.7	40	138.7
15	1515	363.6	3.27	111.2	50	161.2
			No Hydrated Lime			
1	349	83.8	3.27	25.6	10	35.6
2	569	136.6	3.27	41.8	20	61.8
3	792	190.1	3.27	58.1	30	88.1
4	---	---	--	--	--	--
5	1255	301.2	3.27	92.1	50	142.1
6	590	141.6	3.27	43.3	20	63.3
7	373	89.5	3.27	27.4	10	37.4
8	810	194.4	3.27	59.4	30	89.4
9	1061	254.7	3.27	77.9	40	117.9
10	1290	309.6	3.27	94.7	50	144.7
11	384	92.2	3.27	28.2	10	38.2
12	601	144.2	3.27	44.1	20	64.1
13	821	197.0	3.27	60.2	30	90.2
14	1110	266.4	3.27	81.5	40	121.5
15	1326	318.2	3.27	97.3	50	147.3

Note: Load Dial Divisions x 0.24 = Load in Pounds

TRIAXIAL COMPRESSION TESTS

SUMMARY OF MIX PROPERTIES

	3% Lime	0% Lime
No. of Samples Used In Average	14	15
Residual Asphalt Content - %	5.0	5.0
Avg. Dry Weight of Sample - gms	443.4	425.2
Avg. Wet Weight of Sample - gms	485.0	501.6
Dry Density of Mix - pcf	108.2	103.7
Weight of Asphalt - gms	20.6	20.2
Weight of Lime - gms	12.4	0
Weight of Water - gms	41.6	76.4
Weight of Dry Soil - gms	410.4	405.2
Volume of Soil Solids - cc	156.1	154.1
Volume of Sample - cc	255.0	255.0
Volume of Voids - cc	98.9	100.9
Volume of Asphalt - cc	20.6	20.2
Volume of Lime - cc	5.6	0
Volume of Water - cc	41.6	76.4
Volume of Voids in Mix - cc	72.7	80.7
% Voids in Mix Filled With Water	57.3	94.7

Note: All calculations are for samples containing 5% residual asphalt cement.

TRIAXIAL COMPRESSION TESTS ON SAND-EMULSION MIX

5% Residual Asphalt Cement

Rate of Strain = 0.011 in. per min.

Sample No.	1	2	3	4	5
Wt. Wet Sample - gms	498	499	498	495	505
Wt. Dry Sample - gms	420	422	419	423	425
Confining Press.-psi	10	20	30	40	50

Strain Dial (0.001")	Load Dial				
0	0	0	0	--	0
10	75	70	222	--	321
20	145	195	349	--	530
30	193	278	442		675
40	228	337	511		785
50	254	381	571		882
60	275	415	610		950
70	288	452	640		1022
80	298	468	665		1086
90	306	486	684		1117
100	313	503	698		1141
120	331	532	727		
140	338	542	753		
160	344	558	764		1205
180	344	564	775		
200	349	569	792	--	1255
250					
300					1310

Tested: January 18, 1962

TRIAXIAL COMPRESSION TESTS ON SAND-EMULSION MIX

5% Residual Asphalt Cement

Rate of Strain = 0.037 in. per min.

Sample No.	6	7	8	9	10
Wt. Wet Sample - gms	501	498	498	502	505
Wt. Dry Sample - gms	422	423	426	425	427
Confining Press.-psi	20	10	30	40	50
Strain Dial (0.001")	Load Dial				
0	0	0	0	0	0
10	190	140	215	250	135
20	305	208	345	420	310
30	375	247	438	545	555
40	418	275	503	638	681
50	450	292	565	675	830
60	465	305	610	690	910
70	490	315	642	748	980
80	506	325	672		1030
90	519	330	675		
100	528	335	710	950	1105
120	550	346	712	981	1155
140	563		770	1010	1205
160	573	359	785	1028	1250
180	583		797	1045	1270
200	590	373	810	1061	1290
250					
300	615	381	880	1135	1385

Tested: January 18, 1962

TRIAXIAL COMPRESSION TESTS ON SAND-EMULSION MIX

5% Residual Asphalt Cement

Rate of Strain = 0.055 in. per min.

Sample No.	11	12	13	14	15
Wt. Wet Sample - gms	507	505	503	505	506
Wt. Dry Sample - gms	430	430	425	432	429
Confining Press.-psi	10	20	30	40	50
Strain Dial (0.001")	Load Dial				
0	0	0	0	0	0
10	55	60	92	100	145
20	117	180	292	255	427
30	175	268	403	430	575
40	215	330	452	550	680
50	247	380	542	612	795
60	273	420	600	705	900
70	295	448	565	806	973
80	310	468	648	868	1030
90	322	497	691	910	1075
100	331	517	710	945	1110
120	344	548	750	998	1182
140	357		778	1045	1233
160		580	794	1073	1270
180			805	1093	1300
200	384	601	821	1110	1326
250	387	627			
300	400	631	872	1187	1422

Tested: January 17, 1962

TRIAXIAL COMPRESSION TESTS ON SAND-EMULSION MIX

3% Hydrated Lime

Rate of Strain = 0.011 in. per min.

5% Residual Asphalt Cement

Sample No.	1	2	3	4	5
Wt. Wet Sample - gms	482	480	485	484	487
Wt. Dry Sample - gms	444	435	445	434	437
Confining Press.-psi	20	10	30	40	50
Strain Dial (0.001")	Load Dial				
0	0	0	0	0	0
10	150	120		170	170
20			103	365	428
30	222	150	280		
40	358	243	422	675	802
50	445	326	540		
60	506	383	645	870	1035
70	577	423	630		
80	618	439	787	1010	1190
90	648	445	822		
100	680	475	845	1080	1255
120	558	496	935	1118	1300
140		503	962	1140	1328
160		503	969	1162	1344
180		473	975	1173	1365
200		497	990	1183	1378
250		494	1005	1203	1420
300			1015	1225	1455

Tested: January 16, 1962

TRIAXIAL COMPRESSION TESTS ON SAND-EMULSION MIX

3% Hydrated Lime

5% Residual Asphalt Cement

Rate of Strain = 0.037 in. per min.

Sample No.	7	8	9	10
Wt. Wet Sample - gms	482	482	485	487
Wt. Dry Sample - gms	441	446	445	447
Confining Press.-psi	10	30	20	50
Strain Dial (0.001")	Load Dial			
0	0	0	0	0
10	60	194	135	385
20	130	410	310	632
30	220	545	430	800
40	290	680	510	950
50	360	775	600	1020
60	425	800	670	1128
70	460	900	715	1170
80	495	955	665	1190
90	540	990	690	1230
100	571	1010	766	1265
120	520	1040	810	1320
140			832	1352
160	606	1064	836	1375
180			836	1393
200	600	1075	835	1407
250			830	
300	574	1088	300	1463

Tested: January 16, 1962

TRIAXIAL COMPRESSION TESTS ON SAND_EMULSION MIX

3% Hydrated Lime

5% Residual Asphalt Cement

Rate of Strain = 0.055 in. per min.

Sample No.	11	12	13	14	15
Wt. Wet Sample - gms	487	489	486	489	485
Wt. Dry Sample - gms	447	447	445	449	445
Confining Press.-psi	10	20	30	40	50
Strain Dial (0.001")	Load Dial				
0	0	0	0	0	0
10	75	69	195	368	190
20	215	235	397	560	408
30	313	365	530	737	640
40	400	462	642	652	820
50	475	570	772	757	994
60	530	630	900	790	1120
70	610	650	990	830	1212
80	665	687	1048	890	1282
90	630	798	1090	960	1341
100	563	895	1103	1042	1385
120	716	965	1120	1150	1442
140	740	996	1140	1304	1477
160	750	1007	1154	1332	1498
180	760	1010	1158		1509
200	760	1010	1158	1345	1515
250		995		1374	
300	719	977	1163	1382	1558

Tested: January 17, 1961

APPENDIX "G"

MOISTURE-DENSITY-STRENGTH RELATIONSHIPS ON SAND-EMULSION MIXTURES

AND

COMPARISON OF HYDRATED LIME AND SILT AS SECONDARY ADDITIVES

MOISTURE - DENSITY - STRENGTH RELATIONSHIP

Sand-Emulsion Mix --- 5% Residual Asphalt

2" x 5" Statically Compacted Specimens

Sample Number	Dry Sample (gms)	Wet Sample (gms)	Molded Sample (gms)	Water Absorbed (gms)	Molded Water Content (%)	Dry Density of Mix (pcf)	Unconf. Strength (psi)
1-1	391	453					5.93
1-2	395	450					4.79
1-3	395	451					5.53
AVG	393.4	451.1	454.7	57.7	15.6	96.0	5.42
2-1	423	465					6.43
2-2	420	475					6.03
2-3	422	475					5.34
AVG	421.7	471.6	483.7	49.9	14.7	102.9	5.93
4-1	422	469					7.13
4-2	423	473					7.34
4-3	422	472					7.13
AVG	422.3	471.3	468.8	49.0	11.0	103.1	7.20
5-1	440	503					9.95
5-2	438	502					10.55
5-3	433	485					10.38
AVG	437,0	496.7	442.0	59.7	1.1	106.6	10.29
6-1	427	503					5.19
6-2	421	492					4.32
6-3	423	480					4.99
AVG	423.7	490.7	431.7	67.0	1.9	103.4	4.83
7-1	430	478					6.59
7-2	429	477					6.29
7-3	429	485					7.07
AVG	429.3	480.0	429.5	50.7	0.0	104.8	6.65
8-1	433	481					11.25
8-2	429	481					10.25
8-3	429	476					10.05
AVG	430.3	479.3	472.3	49.0	9.8	105.0	10.52
9-1	424	471					10.45
9-2	423	470					9.95
9-3	428	468					12.36
AVG	425.0	469.7	476.7	44.7	12.1	103.7	10.92

MOISTURE - DENSITY - STRENGTH RELATIONSHIP

Sand-Emulsion Mix --- 5% Residual Asphalt

2" x 5" Statically Compacted Specimens

Sample Number	Dry Sample (gms)	Wet Sample (gms)	Molded Sample (gms)	Water Absorbed (gms)	Molded Water Content (%)	Dry Density of Mix (pcf)	Unconf. Strength (psi)
10-1	431	485					10.95
10-2	433	485					10.82
10-3	430	478					10.95
AVG	431.3	482.3	486.3	51.0	12.7	105.4	10.91
11-1	427	477					8.39
11-2	428	483					8.49
11-3	426	478					8.09
AVG	427.0	479.3	462.3	52.3	8.3	104.2	8.32
12-1	430	489					11.15
12-2	432	487					10.45
12-3	434	489					10.95
AVG	432.0	488.3	432.7	56.3	0.2	105.4	10.85
13-1	431	484					8.59
13-2	430	485					8.64
13-3	433	480					10.15
AVG	431.3	483.0	468.0	51.7	8.5	105.3	9.13
14-1	431	493					8.04
14-2	431	486					8.16
14-3	431	486					8.04
AVG	431.0	488.3	453.5	57.3	5.2	105.2	8.08
15-1	426	482					5.93
15-2	427	482					5.99
15-3	427	489					6.03
AVG	426.7	484.3	439.5	57.6	3.0	104.1	5.98

MOISTURE - DENSITY - STRENGTH RELATIONSHIP

Sand-Emulsion Mix --- 5% Residual Asphalt

2" x 5" Statically Compacted Specimens

3% Hydrated Lime as Secondary Additive

Sample Number	Dry Sample (gms)	Wet Sample (gms)	Molded Sample (gms)	Water Absorbed (gms)	Molded Water Content (%)	Dry Density of Mix (pcf)	Unconf. Strength (psi)
1-1	440	489					23.46
1-2	439	491					22.36
1-3	440	490					23.17
AVG	439.7	490.0	489.3	50.3	11.3	107.3	23.00
2-1	445	487					25.86
2-2	443	476					24.96
2-3	440	474					24.61
AVG	442.7	479.0	454.7	36.3	2.7	108.0	25.14
3-1	443	476.5					28.16
3-2	446	478					28.96
3-3	444	477.5					28.46
AVG	444.3	477.3	459.7	33.0	3.5	108.4	28.53
4-1	458	498					33.14
4-2	456	491					33.54
4-3	457	491					37.92
AVG	457.0	493.3	457.2	36.3	0.0	111.5	34.87
5-1	448	504					29.26
5-2	448	504					28.06
5-3	450	507					27.73
AVG	448.7	505.0	498.5	56.3	11.1	109.5	28.35
6-1	458	513					32.25
6-2	458	510					31.75
6-3	457	510					33.06
AVG	457.3	511.0	496.3	53.7	8.5	111.6	32.35
7-1	458	496					35.35
7-2	455	493					35.53
7-3	457	494					37.04
AVG	456.7	494.3	458.3	37.6	0.4	111.4	35.97
8-1	455	496					31.55
8-2	454	495					26.46
8-3	455	497					26.26
AVG	454.7	496.0	476.5	41.3	4.8	110.9	28.09

MOISTURE - DENSITY - STRENGTH RELATIONSHIP

Sand-Emulsion Mix --- 5% Residual Asphalt

2" x 5" Statically Compacted Specimens

3% Hydrated Lime as Secondary Additive

Sample Number	Dry Sample (gms)	Wet Sample (gms)	Molded Sample (gms)	Water Absorbed (gms)	Molded Water Content (%)	Dry Density of Mix (pcf)	Unconf. Strength (psi)
9-1	456	500					30.84
9-2	455	498					26.26
9-3	455	497					31.04
AVG	455.3	498.3	480.0	43.0	5.4	111.1	29.38
10-1	457	504					28.23
10-2	455	504					33.06
10-3	454	502					25.26
AVG	455.3	503.3	480.5	48.0	5.5	111.1	28.85
11-1	455	504					29.04
11-2	455	504					32.53
11-3	454	503					28.16
AVG	454.7	503.7	480.8	49.0	5.7	110.9	29.92
12-1	452	499					28.23
12-2	450	497					25.46
12-3	450	499					24.06
AVG	450.7	498.3	499.5	47.6	10.8	109.9	25.92
13-1	454	500					31.35
13-2	454	503					27.86
13-3	455	502					25.78
AVG	454.3	501.7	494.8	47.4	8.9	110.8	28.33
14-1	452	488					29.56
14-2	452	485					28.38
14-3	455	487					28.67
AVG	453.0	486.7	453.2	33.7	0.0	110.5	28.87
15-1	452	498					25.82
15-2	454	496					28.13
15-3	456	498					28.42
AVG	454.0	497.3	499.7	43.3	10.1	110.8	27.46
16-1	455	503					32.45
16-2	456	506					34.46
16-3	453	503					32.05
AVG	454.7	504.0	486.7	49.3	7.0	110.9	32.99

MOISTURE-DENSITY RELATIONSHIP

Sand-Emulsion Mix — 5% Residual Asphalt

Standard AASHO Compaction Test
5.5 lb. hammer falling 12 inches
4" diameter by 4" high mold -- 1/30 ft^3
25 blows per layer on 3 layers

Sample Number	Wet Sample (gms)	Dry Sample (gms)	Weight of Water (gms)	Moisture Content (%)	Dry Density (pcf)
			3% Hydrated Lime		
1	1733	1515	218	14.4	100.2
2	1507	1466	41	2.8	97.0
3	1532	1487	45	3.0	98.3
4	1413	1411	2	0.1	93.3
5	1776	1558	218	14.0	103.0
6	1900	1735	165	9.5	114.7
7	1505	1495	10	0.7	98.9
8	1725	1634	91	5.6	108.0
9	1683	1593	90	5.7	105.4
10	1704	1610	94	5.8	106.5
11	1702	1604	98	6.1	106.1
12	1813	1603	210	13.1	106.0
13	1858	1702	156	9.1	112.6
14	1619	1619	0	0.0	107.1
15	1860	1667	193	11.6	110.3
16	1840	1705	135	7.9	112.8
			No Hydrated Lime		
1	1625	1374	251	18.3	90.9
2	1780	1544	236	15.3	102.1
3	----	----	---	----	-----
4	1830	1633	197	12.1	108.0
5	1506	1484	22	1.5	98.1
6	1494	1470	24	1.6	97.2
7	1482	1480	2	0.1	97.9
8	1827	1653	174	10.5	109.3
9	1851	1643	208	12.7	108.7
10	1777	1567	210	13.4	103.6
11	1799	1653	146	8.8	109.3
12	1440	1437	3	0.2	95.0
13	1764	1640	124	7.6	108.5
14	1675	1590	85	5.3	105.2
15	1663	1605	58	3.6	106.2

EFFECT OF LIME AND SILT AS SECONDARY ADDITIVES

Sand-Emulsion Mix 5% Residual Asphalt

44 days water immersion

Sample Number	Dry Sample (gms)	Wet Sample (gms)	Water Absorbed (gms)	Dry Density of Mix (pcf)	Failure Strain (%)	Unconf. Strength (psi)
			No Secondary Additive			
1	428.0	486.0			2.0	5.39
2	425.0	487.0			2.4	5.48
3	428.0	491.0			2.4	5.18
4	424.0	485.0			2.0	5.09
5	426.0	487.0			2.4	5.38
AVG:	426.2	487.2	61.0	104.0	2.2	5.30
			3% Silt			
6	431.0	497.0			2.8	7.44
7	429.0	495.0			2.4	7.64
8	431.0	497.0			2.4	7.76
9	432.0	501.0			2.4	7.47
10	432.0	500.0			2.4	7.86
AVG:	431.0	498.0	67.0	105.2	2.5	7.63
			3% Hydrated Lime			
11	437.0	481.0			2.4	22.59
12	440.0	490.0			2.4	22.00
13	439.0	488.0			2.0	22.07
14	441.0	491.0			2.4	21.10
15	439.0	490.0			2.4	21.10
AVG:	439.2	488.0	48.8	107.2	2.3	21.77

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